School of Engineering

INDD341 Individual Design Project - Final Report

Double-Back Backrest Design of Dental Chair which Equipping Mainstream Dental Services for Lower End Bariatric Patients

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May 2021

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Abstract

Levels of obesity in the UK were increasing (NHS, 2020), and oral care services were needed to meet the needs of these patients so that they could access effective care. Bariatric patients were faced with potential barriers and safety risks when they got oral care, and the existing dental chair had numerous usability issues. These include the weight limits of the dental chair, inappropriate seating in the waiting area, inadequate toilet facilities, narrow corridors and the presence of stairs but no lift. Negative experiences and anxiety around accessing dental care can result in disengagement with services and ultimately lead to poor oral health. Therefore, this project aimed to investigate bariatric oral care provision, pathways, and accessibility issues, and then provided a product that could equip mainstream dental services for lower end bariatric patients. It's able to encourage them to stay engaged with dental services, preventing oral hygiene decline, rather than only accessing care in an emergency.

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1 Project Introduction

1.1 Introduction

In the United Kingdom, obesity was on the rise (NHS, 2020), and bariatric patients faced several health problems. When they sought conventional dental care, they often encountered barriers to receiving high-quality service and treatment, including an uncomfortable waiting room chair, a lack of toilet facilities, an inability to use a normal dental chair, a lengthy referral procedure, and difficulty using a bariatric dental chair. Due to the weight limitation of a regular dental chair, bariatric patients were not permitted to use it and must receive special care. On the other hand, current bariatric dental chair solutions were difficult to use, which frustrates dentists and results in a negative patient experience.

The project aimed to improve bariatric patients' experiences and produced an equal design outcome in order to ensure they receive high-quality treatment. Patients who had undergone bariatric surgery were especially susceptible to oral health problems. The designer hoped that by facilitating patient access to treatment and providing a positive experience, patients would continue to use oral health services and prevent serious health problems.

1.2 Initial Design Brief

This project will seek to investigate and improve the experiences of bariatric patients through:

a. Brief exploration of bariatric oral care provision, pathways and accessibility issues
b. Detailed analysis and redesign of a bariatric dental chair.

The outcome of this project will be a design improvement to a bariatric dental chair, with a focus on Usability. The solution could be the redesign of an integral feature, a modular add-on, or a separate product.

2 Literature Review

2.1 Obesity on the rise

Obesity is a global public health problem that has been associated with a variety of physiological diseases. It is quantified using the Body Mass Index, which is

calculated as follows: BMI = Individual's weight (kg) / Individual's height (in metres²). A BMI of greater than 30 kg/m² indicates obesity, while a BMI of greater than 40 kg/m² indicates morbid obesity (NHS, 2020). According to the 2019 Health Survey for England (Baker, 2021), 28.0 percent of adults in England are obese, while 36.2 percent are overweight but not obese. Additionally, the report found that 9.9 percent of children of receiving age (4-5 years old) were obese, while 13.1 percent were overweight. 21.0 percent of children aged 10-11 (6 years) were obese, while 14.1 percent were overweight. This figure indicates that an increasing proportion of people would become overweight or obese in the future. A BBC report (BBC, 2021) highlights this problem, as illustrated in Figure 2.1.1.

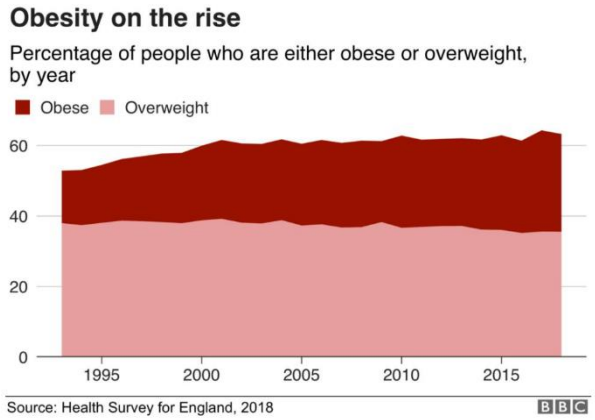


Figure 2.1.1: Percentage of people who are either obese or overweight, by year(BBC, 2021)

2.2 The importance of oral care service

Obesity is linked to a number of chronic diseases, including hypertension, high cholesterol, stroke, kidney disease, and cardiovascular disease, and is also a major risk factor for oral diseases (Reilly, Boyle, and Craig, 2009). Obese people are twice as likely to die of coronavirus disease as average people, according to a study of NHS electronic health records. When fat content has an effect on the immune system's activity, the antigen response can be altered, resulting in an inflammatory reaction disorder during the course of the periodic disease. Complications are more likely to occur in dental treatment. Additionally, there is a connection between obesity and dental caries (Anderson et al, 2009). Obese patients are thought to be more susceptible to dental disease and their dental health continues to deteriorate. Additionally, the treatment process is more complicated and needs the utmost attention from dentists.

The Equality Act outlines in detail everyone's right to fair access to medical care, including disabled and obese individuals (Legislation.gov.uk, 2010). The medical system must take individual groups' needs into account and provide

non-discriminatory, adequate care. With a rise in BMI, an ordinary dental chair becomes incapable of supporting obese patients. They are often unable to receive care in standard community clinics for safety reasons and are directed to specialized clinics fitted with bariatric dental chairs (Geddis-Regan et al, 2019).

2.3 Bariatric patient experiences in accessing oral care services

Obese patients will encounter numerous barriers when obtaining oral care, the procedure process, and referral, including unsuitable waiting room chairs, insufficient toilet facilities, short corridors, and difficulty using the dental chair. Throughout the operation, the patient's perspective is often difficult to comprehend. Negative emotions and anxiety impair their ability to seek treatment effectively, jeopardizing their oral health.

The level of care provided to obese patients is not encouraging. According to a study conducted in North Wales (Dowey, 2017), more than half (57%) of dentists and therapists agree that the present standard of dental treatment available to this group of people is poor / very poor, owing primarily to a lack of instruction and suitable facilities. Dentists identified dental chair problems as the most significant barrier to providing treatment to bariatric patients. Simultaneously, the number of bariatric scales available is inadequate, and patients often underestimate their weight, making it difficult to obtain accurate weight data on patients.

Psychological problems encountered by patients when receiving nursing care should also be considered. All patients shared their stigma and shame in a review of patient care pathways in northeast England (Geddis-Regan et al, 2019). When they are subjected to weight discussions, even if it is unintentional, they feel discriminated against and treated unfairly. They may also lack trust in the quality of treatment or believe they received substandard service. They would also feel overwhelmed if there are inadequate or lack of facilities. At the same time, improper referral and inconsistent care will cause undue distress. A negative experience may cause a patient to discontinue dental care, which may result in potential oral and general health problems.

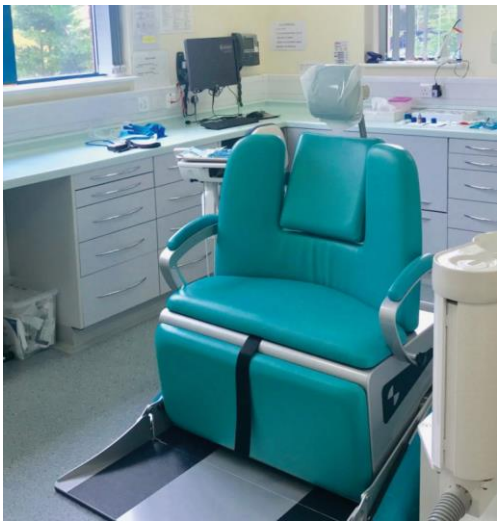


Figure 2.2.1: A bariatric dental chair in a community dental service (Geddis-Regan et al, 2019)

Figure 1 shows an example of a bariatric dental chair in a community dental service.

Additionally, obesity can result in a variety of medical comorbidities, which raises the risk and complexity of treating oral diseases. For instance, a case study of a woman (Malik, 2019) revealed that she suffered from a number of comorbidities as a result of her class 3 obesity (BMI of 65 kg / m^2). She underwent surgery using a bariatric dental chair and local anesthesia. To maintain an open airway, she sat semi-supine, making it impossible for doctors to find and operate. To alleviate the pain caused by her lower limb pressure ulcers, she must use a pad. Additionally, the crane is kept accessible at all times to avoid the need for an unexpected emergency shift. Since bariatric patients have access problems, the process of sitting up and getting out of the chair can be challenging. Transferring patients efficiently and safely is a challenging aspect of care. Changes in total blood volume, cardiac function, and respiratory function place the treatment under stress and increase the risk of metastasis.

3 Project Aims and Objectives

3.1 Project Aims

The project aims to investigate and improve the oral care experience of bariatric patients, including investigation of service process, pathway, availability, and improvement or redesign of bariatric dental chair. The final product may be a redesign of the overall function, a separate product or an added component, which will be decided in the subsequent process. The design will be human-centered, understand the patient's physiological and psychological factors, and

develop an inclusive solution.

3.2 Project Objectives

Multiple objectives need to be accomplished to achieve this aim.
The first objective is to carry out extensive research on the subjects involved in this topic, including patients, dentists, dental chairs and clinics. The experience of bariatric patients and their physiological and psychological difficulties need to be explored. At the same time, from the dentist's point of view, we can know another aspect of dental chair use, including headrest angle, height and so on. Technical analysis of dental chair and clinical analysis will also be taken into account.
The next objective is to identify the target population and create a persona. Make PDS and house of quality according to user requirements, determine the demand list of products, and find the most important part. Then brainstorm and generate the initial idea.
The third objective is to analyze the existing solutions to determine the final solution, including dimensions, details, materials, etc. Some design methods will be used, which will be discussed in the next section.
The final objective is displayed, including hand drawing, CAD modeling, prototype production. In this stage, modeling software such as 3DMAX and Creo is needed, and some material support is also necessary. This part will be mentioned in the detail design section.

4 Methodology

4.1 Design Approach

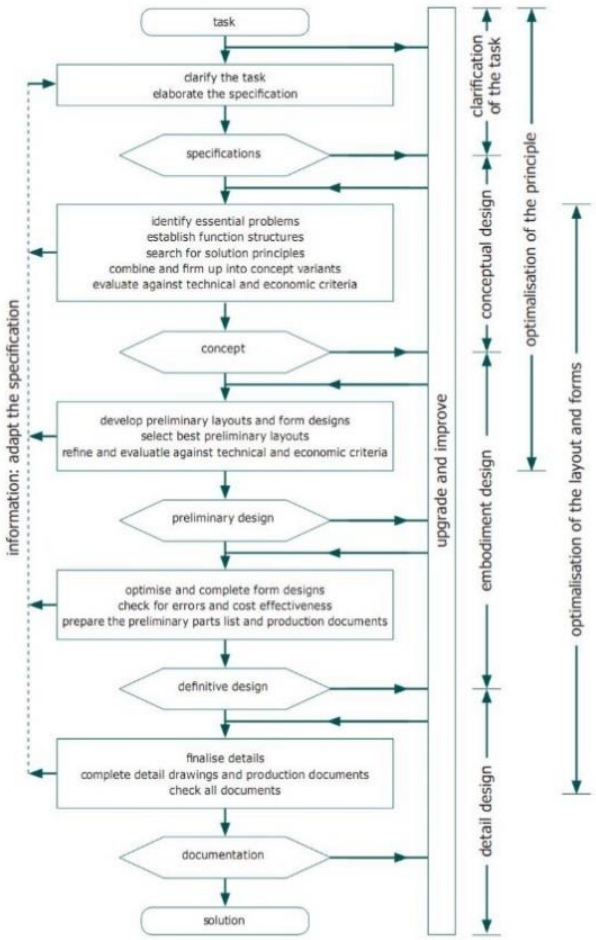


Fig. 4: The Pahl & Beitz systematic design approach as a flow chart

Figure 4.1.1: The Pahl & Beitz model (Schaefer & Milisavljevic-Syed, 2020)

The Pahl & Beitz model will be used to guide the design process for this project (Schaefer & Milisavljevic-Syed, 2020). This design procedure follows a structured approach that consists of four stages: task clarification, conceptual design, embodiment design, and detailed design.

The first stage investigates the background, collects information, and identifies design issues. Following the formulation of the design specification, the completion date for each mission shall be specified, and modifications and refinements which occur at any time.

The second step produces a wide range of solutions, which are then analyzed according to a variety of parameters. Typically, it begins with specifying the overarching feature and critical sub-functions and then combines them into the overall solution.

The third stage is to determine the final design, which includes the form, scale, material, and other characteristics of the product. A prototype was created to evaluate and develop the product's performance, service, and use.

The fourth stage is the detailed design, which may include renderings of the final design or object creation. Additionally, production, transportation, and demand would be considered.

These four steps are progressive processes. If there are some roadblocks or challenges along the way, designers can return to the previous step for

correction. Before initiating each step, it is necessary to ensure its credibility and operability. Since this design approach has been used several times in previous projects, experience with it may help me perform better.

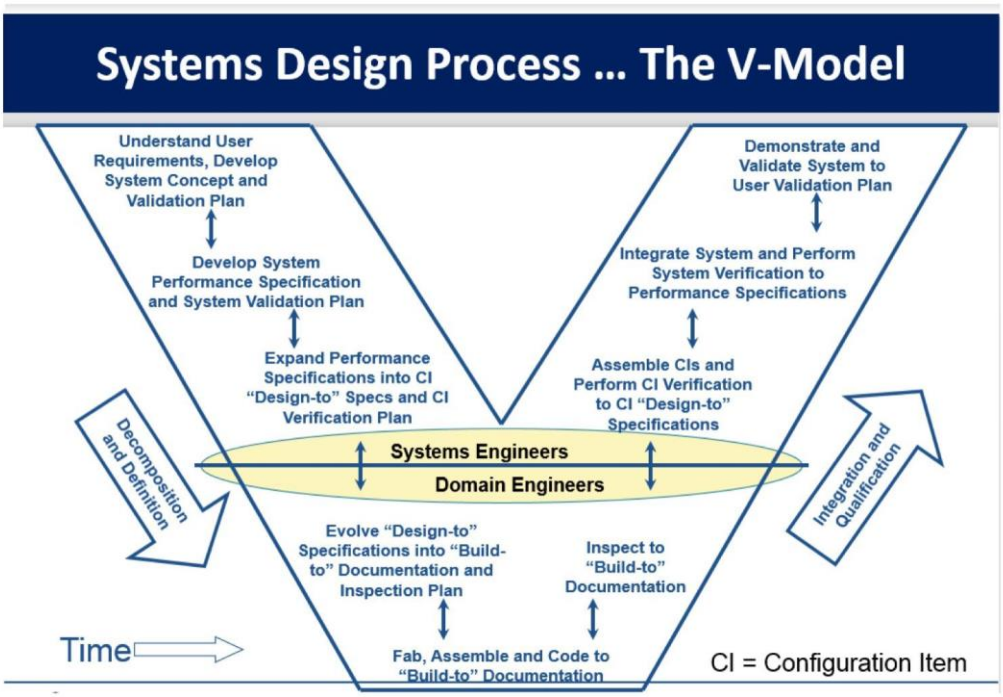


Fig 2: A typical Vee Model as a representation of a systems design process

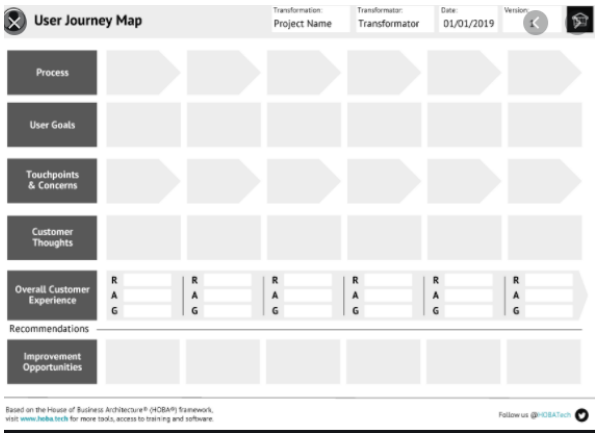
Figure 4.1.2: A typical Vee Model as a representation of a systems design process(Schaefer & Milisavljevic-Syed, 2020)

Simultaneously, the Vee Model would be considered (Schaefer & Milisavljevic-Syed, 2020). A dental chair is a product designed for a particular use. If the design is divorced from the clinic setting, it may deviate from reality. I want to expand my thinking and bring device architecture into the design process. By employing this model, I am able to concentrate not just on the product itself, but also on how it communicates with the external world and computers. The machine architecture segmentation of the product discusses how its subsystems should be applied as a whole. Despite the fact that this design approach is nuanced and needs advanced domain experience, I intend to challenge myself and contribute to the final product's positive effect by systemic design.

4.2 Methodology

Reading the required literature, journals, articles, directories, and other materials during the early stages of the project is the most efficient way to easily acquire the necessary background. Since oral-service and bariatric dental chairs are not widely known in the medical community, it's difficult to find

related articles or comments on social media platforms. Due to the unique characteristics of patients (the majority of whom are reluctant to discuss their weight and inadequate medical experience, and I have no means of contacting them for privacy reasons), interview and questionnaire forms would be disregarded. Customers' and doctors' interests can be determined by detailed journal articles, such as interviews with patients and dentists in a certain field, case studies, and so on. A consultation with a dentist may also be a valuable source of research.



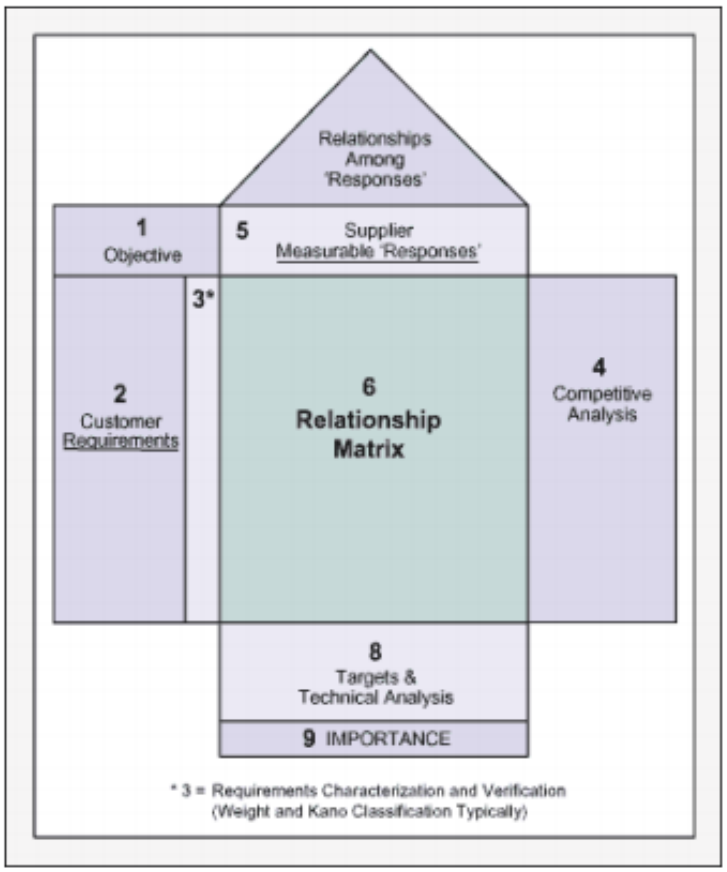
After sorting out the information, a journey map will be developed, visualizing the whole process of patient appointment, medical care, and referral. In each step, the user's difficulties (both physical and emotional) will be found.

Figure 4.2.1: example of journey map (HOBA TECH LTD, 2021)

The user's requirements will be specified by the journey map. The following table will be included. It outlines the physical and psychosocial issues and obstacles associated with current goods and services identifies opportunities and potential changes and highlights important points. This will assist me in identifying user experience challenges and identifying additional resources from an open design perspective.

User Requirements Statement	
Physical	
Issues & Challenges	1. 2. 3.
Pain Pont	
Opportunities & ideal experience	1. 2. 3.
Pleasurable points	
Psychosocial	
Issues & Challenges	1. 2. 3.
Pain Pont	
Opportunities & ideal experience	1. 2. 3.
Pleasurable points	

Figure 4.2.2 example of user's requirements list



House of Quality can be used to identify the product's critical functions and to prioritize the functions that fulfill the user's expectations using the relationship matrix.
Then, the PDS will be generated based on the HOQ data. I will learn about the product's characteristics from the PDS, which will serve as a standard and guideline for future product production, ensuring that the final product will not fail.

Figure 4.2.3 example of House of Quality (UoL, 2020)

Figure 4.2.4 Design Kit logo (Design Kit, 2021)

In the conceptual design and assembly design stages, some human-centered approaches will be used. The techniques I studied in the RSA project course can be seen as a guide. According to the design kit's navigation, I put bariatric patients at the forefront of my design problems and proposed a human-centered design approach with step-by-step creative navigation.
Several human-centered approaches will be used in the conceptual design and assembly design phases. The methods I learned from the RSA project course can be used for reference. According to the navigation of design kit, through step-by-step innovative navigation, put bariatric patients at the center of my design problems, and put forward a human centered design method.

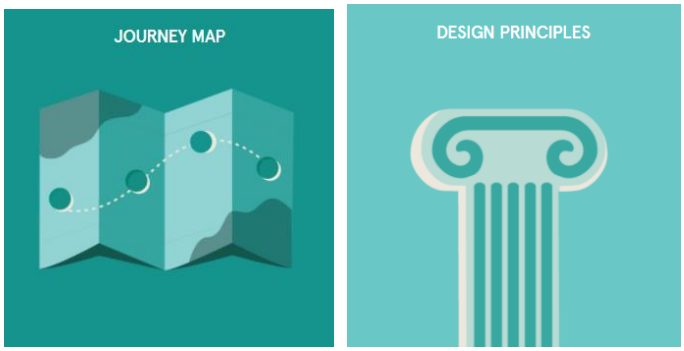


Figure 4.2.5 Design Kit approach example 1 (Design Kit, 2021)

For example, the journey map mentioned above will be used, the PDS will be used as design principles.

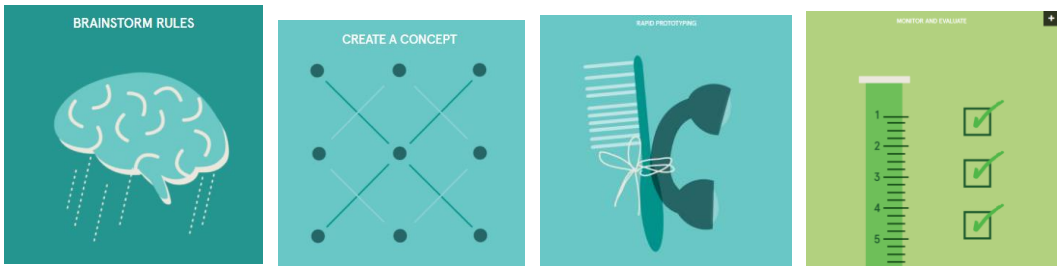


Figure 4.2.6 Design Kit approach example 2 (Design Kit, 2021)

Brainstorming is used to generate ideas. Following that, I will use the process of constructing ideas and Rapid Prototyping to choose an idea to present. The intelligent calculation may aid in the selection of the most suitable solution.

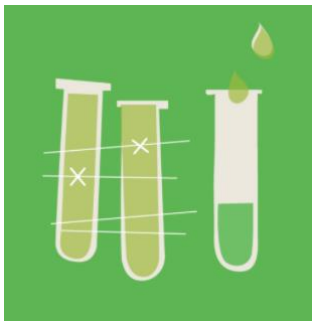


Figure 4.2.7 Design Kit approach example 3 (Design Kit, 2021)

The most important principle is to continue iterating. Testing, reviews, and iteration would both contribute to the project moving in a more business- and customer-driven direction. There is no such thing as optimal design; only superior design exists. When a product is introduced to the market, there are still opportunities to improve it.

The detailed design will begin with a hand drawing and will culminate in a two-dimensional presentation of the design scheme and effect. When a problem occurs, it can be corrected more easily and effectively. Following the development of the product drawing (including its dimensions, material composition, and joints), 3D modeling software such as 3DMAX or C4d is used. If pressure testing is needed to ensure mechanical properties, Creo is required. After the establishment is complete, paste materials and render the final renderings. No real model was developed in 2021 due to the novel coronavirus pneumonia.

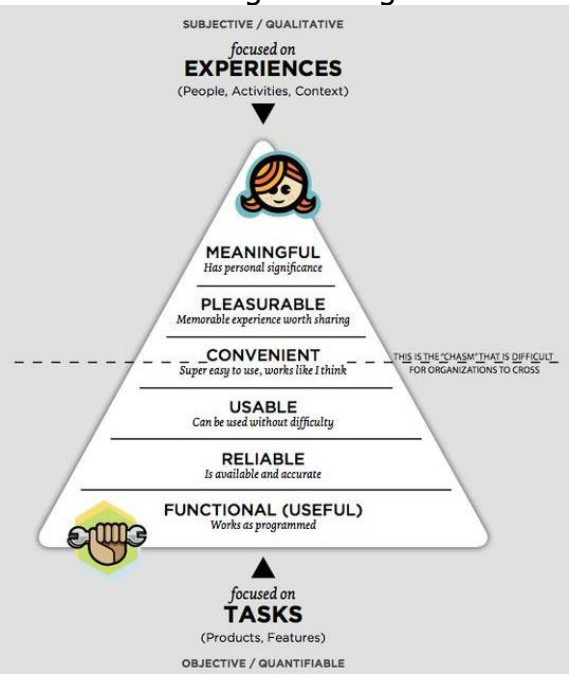


Figure 4.2.8 User Experience Hierarchy of Needs mode (Tod, 2021)

5 Customer requirements and analysis

5.1 Persona and user group

Two distinct personas were created to reflect two distinct groups of dental chair users. By designing personas, designers can easily grasp the user's desires, knowledge, actions, and expectations, lead the designer's creative process and accomplish the objective of providing a positive user experience for the target user community (Dam and Teo, 2021).

James Brown was a fit, average-weight college instructor. He visited the dentist on a daily basis, maintains excellent oral health, and encountered no barriers when using oral care. Alexander Bush's health situation, on the other hand, was less positive, as he was obese and thus unable to see a dentist in a standard dental clinic, and his disappointing referral history had left him with negative feelings about seeing a doctor. He hardly performed oral treatment unless there was an emergency, further jeopardizing his oral health.

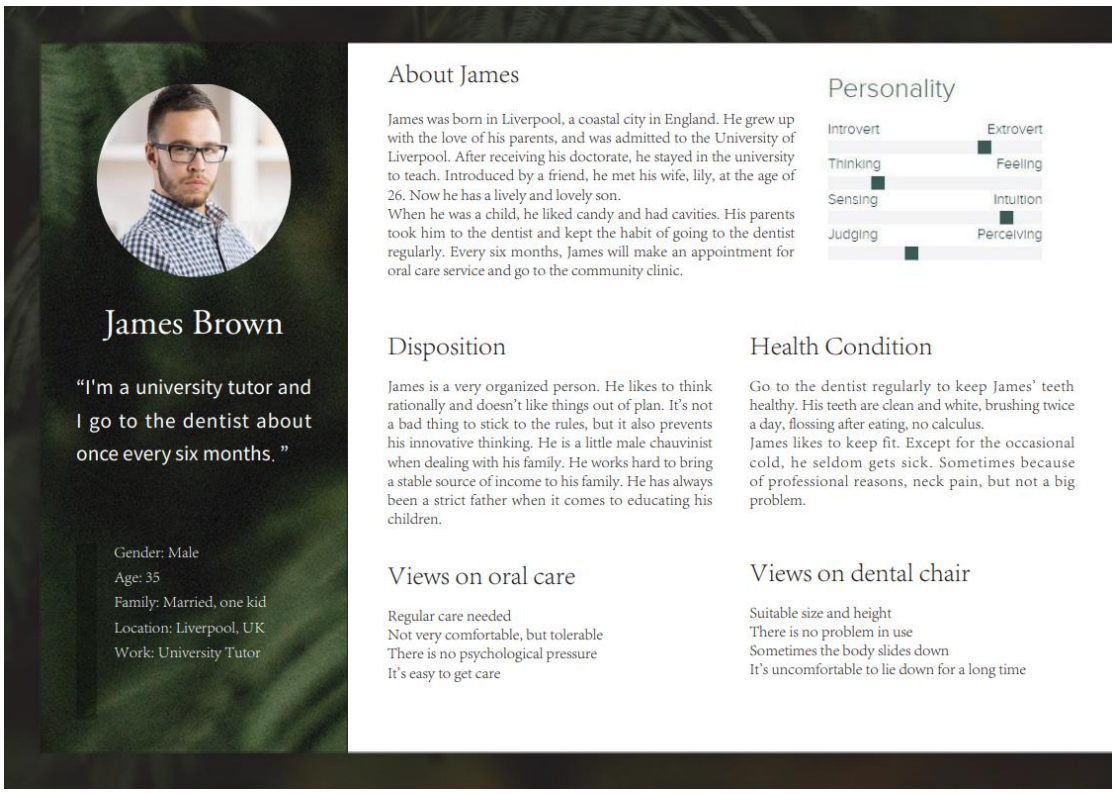


Figure 5.1.1 Persona 1, normal patient

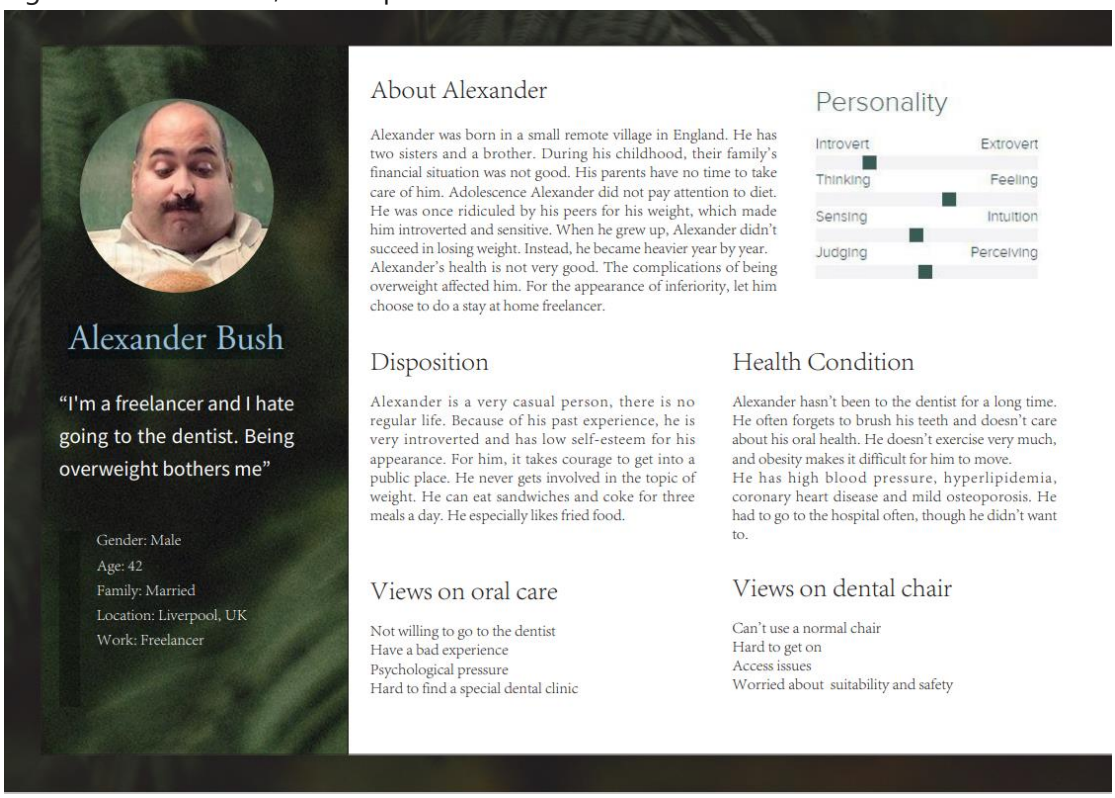


Figure 5.1.2 Persona 2, bariatric patient

The user group is not identified at this time since we must discuss the maximum weight range with the dentist. As a result, the figure was created following the

visit with the dentist. By including user groups here, I believe that this project becomes more understandable. As a result, we've moved it up the priority list.

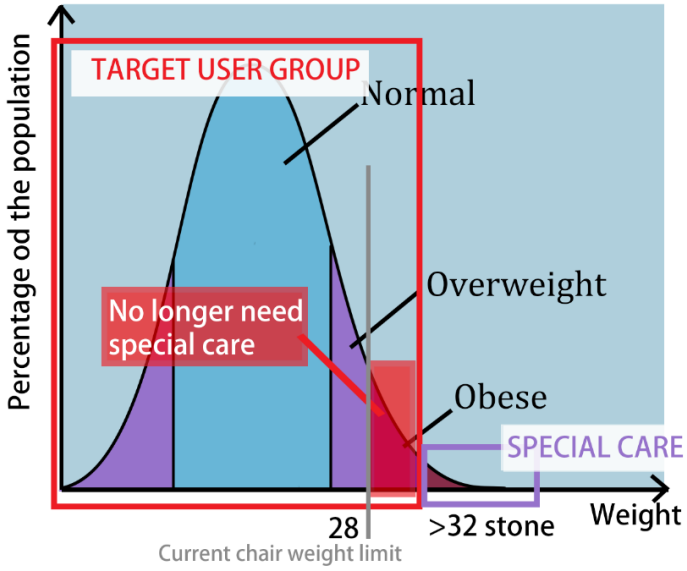


Figure 5.1.3 User group

User group included users of existing mainstream dental chairs PLUS people under 32st. (The data 32 will be determined after the meeting with the dentist)

User group not include:

- people over this weight since they are often in a wheelchair and have more complex needs
- Patients who require special care services for other reasons e.g. disability

5.2 User Journey Map

The user journey map depicts the medical journeys of bariatric patients such as Alexander bush. In comparison to routine patients, they would face frequent appointment requests and lengthy referral wait times. The clinic's insufficient services created havoc and an unpleasant atmosphere. The talk of weight embarrassed and humiliated the patient. They thought they experience discrimination as a result of the special dental chairs. In general, the oral treatment experience of patients undergoing weight loss was unpleasant.

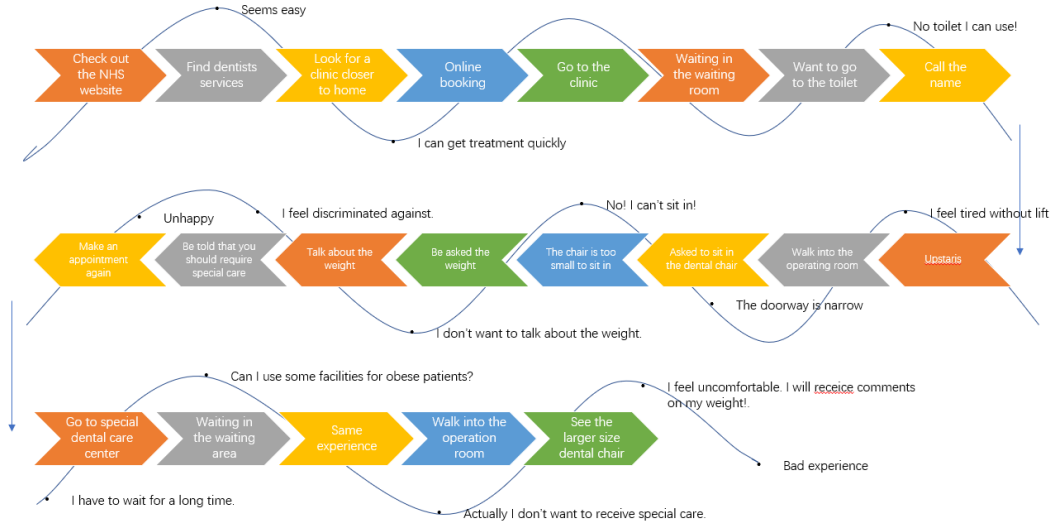


Figure 5.2.1 User Journey Map

5.3 User Requirements Statement

Table 5.3.1 showed the user requirements statement. The template of this form was provided by the supervisor. It described the problems and challenges, pain points and improvement opportunities in the process of using existing products (taking Design Specific as an example) from both physiological and psychological aspects.

Table 5.3.1 User Requirements Statement

User Requirements Statement	
Physical	
Issues & Challenges	1. Too narrow 2. Insufficient support (unable to go up) 3. Improper head position (hard to operate) 4. Ergonomics (sedentary leg numbness, waist pain) 5. Access issue due to obesity 6. Stability and safety
Pain Pont	Size, structure, ergonomics
Opportunities & ideal experience	1. Spacious seats 2. Enough support 3. Good ergonomic design 4. Improve access issues 5. More stability and security
Pleasurable points	Meet users' needs

Psychosocial	
Issues & Challenges	1. It's uncomfortable to see chairs of different sizes 2. Feel embarrassed and stigma to go to a special clinic 3. Refuse to discuss weight 4. Resist going to the dentist (because of the bad experience)
Pain Pont	Shame, embarrassment, stigma
Opportunities & ideal experience	1. Design a dental chair that can be used by ordinary patients 2. Be able to quickly and accurately know the patient's weight 3. Optimize the service process 4. Make the patient feel pleasure and relax
Pleasurable points	Users' Psychology

5.4 House of Quality

Utilize a house of quality to convert consumer needs into products that follow technological specifications. To begin, compile a list of customer requirements and measure their percentage, followed by functional and technological requirements. Demonstrate the value of technical specifications by describing the relationship between technical requirements and consumer requirements in terms of strength. Information can be found in Figure 5.4.1.

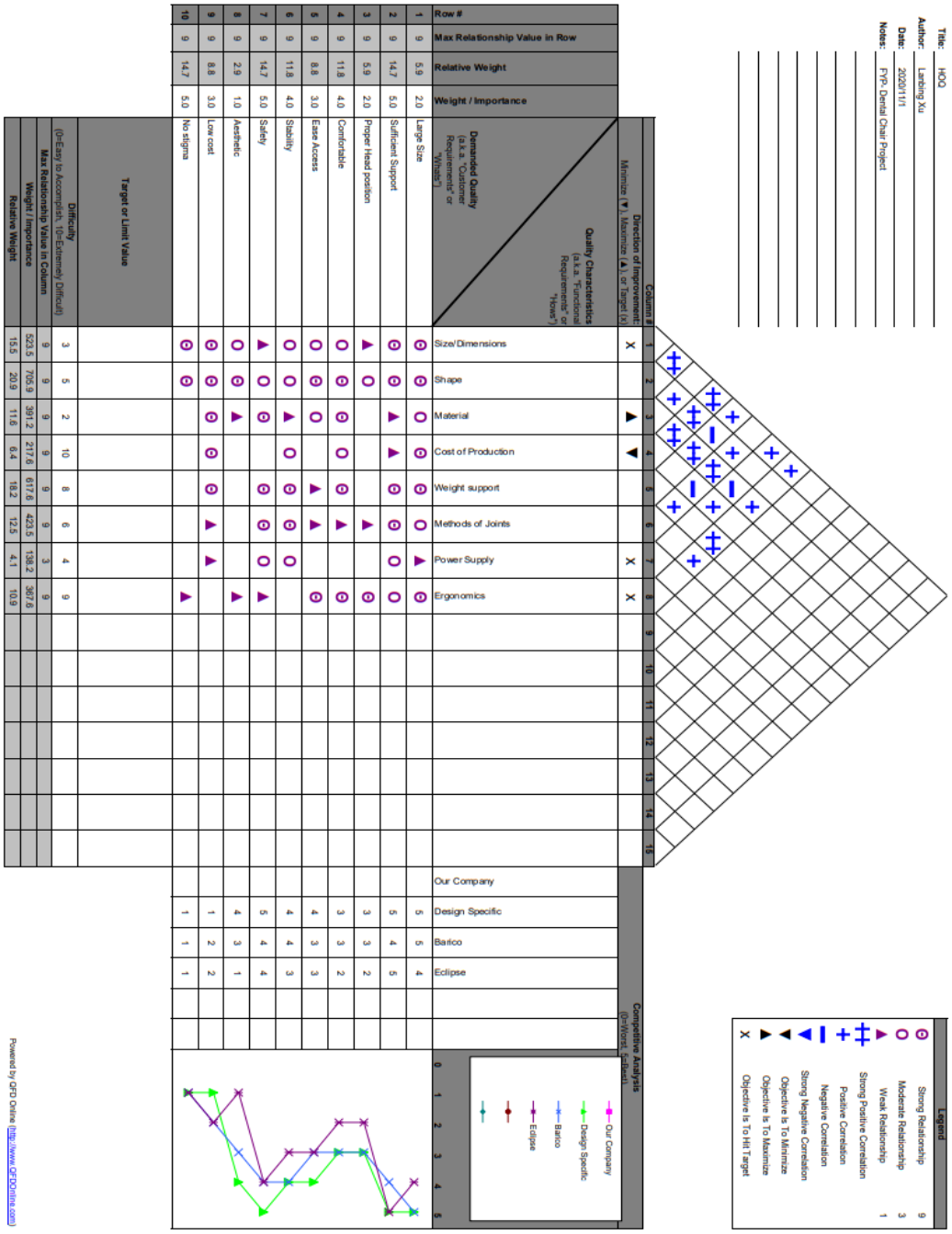


Figure 5.4.1 House of Quality

As can be seen from the table, consumers were most concerned with providing support, safety, and no stigma. The product size, shape, and weight support were the most important reference standards. When analyzing competing goods, the three companies generally ignored the psychological criteria of consumers and excelled at product practicability and protection. This would be discussed in more detail in the subsequent market analysis.

6 Market and Competitor analysis

6.1 Market research

Dental equipment specifically designed to treat obese patients is scarce on the market. The distribution of space, the high price and the problem of usability all hinder its large-scale production and use in the field of oral care. At present, the number of dental chairs in use in the UK is limited, mainly including the following six types.

Bariatric treatment chair produced by design specific (Design Specific, 2019) is an innovative solution with low height (500mm) and high load-bearing. When it tilts the back, the position of the headrest remains the same and can be adjusted manually to provide proper support for the patient. When the seat is raised, the leg bracket can be extended to avoid sliding of the patient's legs. It's powered by batteries and can be used to secure child seats.

Figure 6.1.1: Bariatric treatment chair (Design Specific, 2019)

Figure 6.1.2: Combination of bariatric bench and compact wheelchair recliner (Design Specific,

2019)

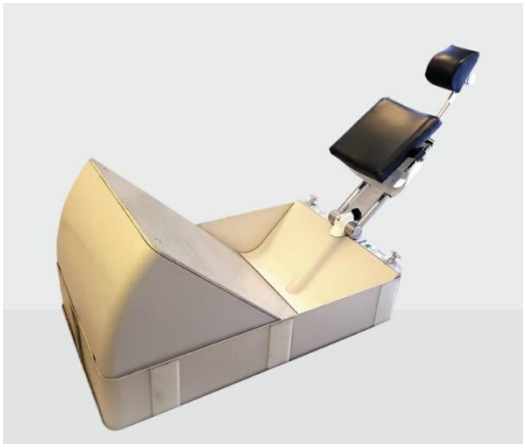
Figure 6.1.3: Compact wheelchair recliner (Design Specific, 2019)

Figure 6.1.4: bariatric bench (Design Specific, 2019)

Another dental device designed by design specific was composed of bariatric bench (Design Specific, 2019) and compact wheelchair recliner (Design Specific, 2019). It is a wide dental couch with full soft tissue support, without cumbersome industrial fixtures or installation procedures, which increases work efficiency and economic use of space.

Transport and treatment chair (Design Specific, 2019) were the third solution of design specific. It is designed to transport heavier patients decently, and it can also be tilted to 45 degrees. But its head support can't move.

Figure 6.1.5: Transport and treatment chair (Design Specific, 2019)



The full function wheelchair platform (Design Specific, 2019) is not strictly a dental chair device. It is a tilting wheelchair platform that allows patients to sit in their wheelchairs for dental treatment. It is more used to treat disabled patients, but as obese patients with limited mobility, this solution can also be considered.

Figure 6.1.6: The full function wheelchair platform (Design Specific, 2019)

The bariatric dental chair (Barico, 2010) is suitable for dental patients under 1000 pounds. It has a minimum height of 44cm. It has a hand and foot controller and does not need to be fixed on the ground. Have comprehensive security certificate, can shrink, height can be adjusted, can also move.

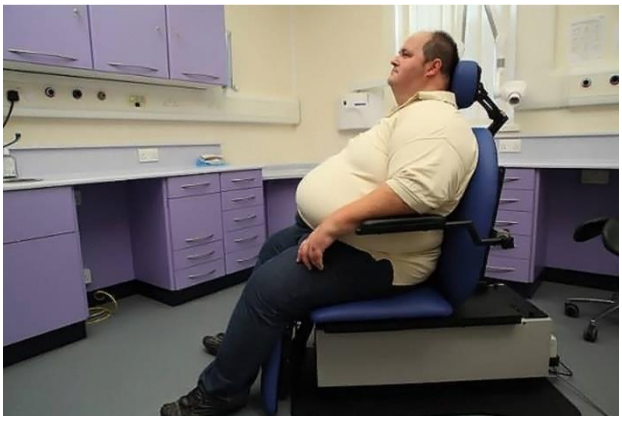
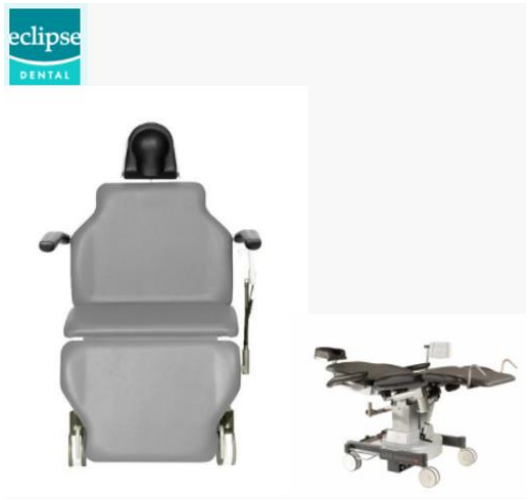


Figure 6.1.7: The bariatric dental chair (Barico, 2010)



The 500 XLE bariatric surgical chair (Eclipse, 2021), produced by eclipse, can hold 770 pounds of people, is powered by batteries, can rotate 360 degrees, and use buttons to control lifting.

Figure 6.1.8: T The 500 XLE bariatric surgical chair (Eclipse, 2021)

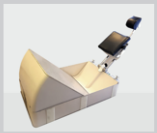
That's the bariatric dental chair that can be found. Historically, there was no dental chair for special groups in the past. With the rise of obesity rate, there is a growing demand for this market, but there are not enough good enough

products to meet their oral care needs. At the same time, special dental chairs are expensive and only available in specific clinics. Research and improvement of the existing dental chair, increase the usability and practicability, will be in line with the direction of future medical development.

6.2 Competitor analysis

Table 6.2.1 shows a comparison of six products from three companies that manufacture special dental chairs. All of the existing bariatric dental chairs are very expensive (Eclipse's chair price is £ 12,971.00). The weight bearing capacity is high, which provides enough support for overweight patients. While Design Specific has the most variations and is the most stunning, Eclipse's product is the most difficult to use.

Table 6.2.1 Competitor analysis

Company	DESIGN SPECIFIC	DESIGN SPECIFIC	DESIGN SPECIFIC	DESIGN SPECIFIC	barico	eclipse DENTAL
Product						
Highlights	design of equipment for bariatric patients Best seller	A removable seat that can be added to the Compact Wheelchair Recliner	designed specifically for both the transport and treatment of obese patients in a comfortable manner	allows dental patients to remain in their own wheelchair during medical treatments	suitable for all patient groups up to 1000lbs (454kgs 71st	Suitable for bariatric patients
Usability	Low seat height of 500mm optimal support can be achieved for all patient	combining the heavy lifting capabilities of the Compact Wheelchair Recliner with the need for economic use of space	Motor Drive Assist to transport heavy patients with ease	Compatible with motorised and manual wheelchairs Fully adjustable wheelchair backrest support	Fully functional armrests and headrest Trendelenburg position	It can move as a wheelchair
Shortcoming	Very expensive Sometimes not very easy to use	Expensive Inconvenient to move	It can only be used for transportation	Patients without wheelchairs cannot use	The operation is slow Expensive Ddifficult to use	Hard to use Lack of design

7 Translating customer requirements into a PDS

A product design specification (PDS) is developed to detail the requirements that the product must meet. It is a declaration of the customer's objectives for the product and should be prepared to serve as a guide for design objectives. As shown in the table 7.1, the specific requirements of products will be elaborated from three categories of product design & performance, market and capability.

Table 7.1: Product Design Specification

Product Design Specification			
Wishes/Demands (W/D)	Category	Requirements	Explanation
A. Product design & performance			
D	Expected product size and weight	Similar weight and size	The product should be modified on the existing dental chair, with similar weight and size. Be able to adapt to the clinic environment.
D		Chair length	Wide enough
D	Expected product performance requirements	Operational requirements	It can carry overweight patients to complete the actions needed by dental care. Make the patient in a comfortable and convenient position for surgery, and allow the doctor to adjust the height and head position of the patient. Height Adjustment. Swivel Feature.
D		Product service life	More than 10 years
W		Tell the weight	Be able to quickly and accurately know the patient's weight
D	Expected product service environment	Clinic	Standard clinic environment.
D		Exposure to extreme weather conditions	Corrosion resistant, not easy to rust, easy to clean. Easy to maintain.
D	Expected product safety requirements	Safe & Support	In line with national product standards. It has high security. Safety guarantee for patients and doctors (weight bearing, etc.). Safety during assembly (leakage, etc.). Product stability in frequent use.

D	Expected product reliability standards and requirements	Headrests.	Small and Thin Headrests.
D		Backrest.	Narrow Upper Backrest.
D		Armrests	Adjustability. Sling-Style or Low-Profile Armrests
W	Expected product ergonomic requirements	Ergonomic	Focusing on the ergonomic features of patient chairs. Comfortable.
W	Expected product aesthetics	Aesthetics	Allow the patient to relax and feel pleasure.
D	Expected product maintenance requirements.	Maintenance	The product needs routine maintenance to ensure safety. Simple maintenance operation
D	Material requirements	Material	It is safe and non-toxic to human body. Corrosion resistant, waterproof. Environmental protection (if possible)
B. Market issues			
	Potential customer base	Customer base	Clinic. Special clinic. Medical department procurement.
D	Target product price	Low Price	It's cheaper than existing products.
C. Capability issues			
W	Company constraints on product design, manufacture, and distribution.	Company	The technical difficulty does not exceed the scope of ability. Cooperate with medical institutions. The manufacturing process can purchase existing parts, or modify on the basis of the original products.

8 Concept generation

8.1 Brainstorming

After gaining a thorough understanding of the product specifications, brainstorming is used to generate initial concepts. Though feasibility will be disregarded, transparency and imagination will be encouraged. Designers can concentrate on creating as many designs as possible in order to broaden the scope of development.

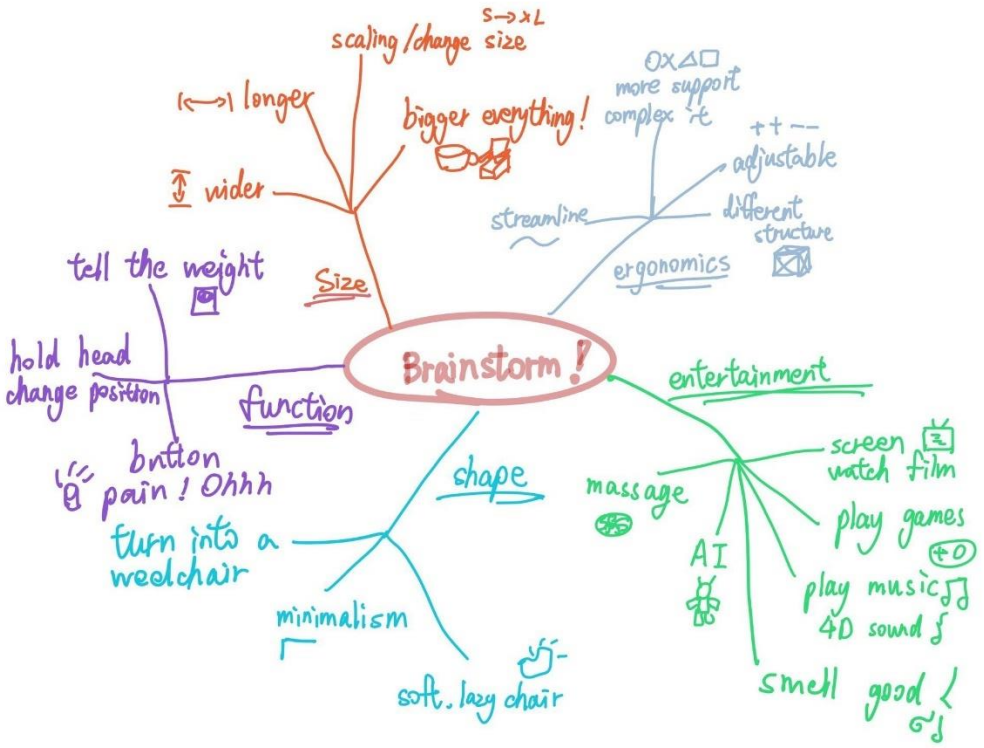


Figure 8.1.1 Brainstorm

The items are classified into five groups for consideration, ergonomics, entertainment, shape, function, and size, as depicted in figure 8.1.1. The following table 8.1.2 shows the details.

Table 8.1.1 Brainstorm

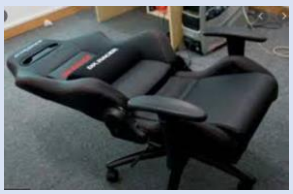
Brainstorm	
Classification	**Idea**
Size	Make dental chair longer
	Make dental chair wider
	Different chairs, such as s, x, l, XL
	Make everything in the dental clinic bigger. Let the bariatric dental chair not stand out.

Function	When people sit on it, can directly measure their weight
	The headrest can be adjusted in different positions and angles
	With a button in the hand, patients can express themselves by pressing the button when the mouth is not convenient to speak
Shape	Turn it into a wheelchair
	Make it can be fold and get smaller
	Lazy chair, more soft and comfortable
Entertainment	The chair has massage function.
	There is a screen in front of the head to watch movies
	There are game handles and screens for playing games
	There is a music player on the headrest, which can play music around the ears
	Make it smell good
	Add AI robot function, such as dialogue
Ergonomics	Streamlined shape
	Add components to provide more support
	Make the dental chair adjustable
	Change structure, use new technology

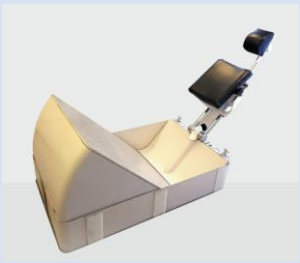
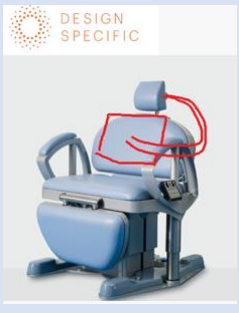
8.2 Concept generation

This project does not require me to design an entire dental chair; rather, I am required to design a single component. The outcomes of brainstorming are extremely diverse and can be applied to a variety of areas, such as weight detection in the functional grouping. That may be a new gadget or an enhancement to the existing one. As a result of brainstorming, the author developed a more detailed conceptual concept. This section is split into three subheadings. The first consideration is redesigning the current dental chair. The second aspect is the improvement of the dental chair produced by design specific, and the third aspect is the additional device added to the dental chair produced by design specific. As shown in the table 8.2.1.

Table 8.2.1 Concept generation

Concept	Diagrammatic sketch	Advantage
Redesign		
Bed-like chair		A very wide folding bed-like chair It's Square and can be folded into the wall Saving space, comfortable (like a bed)
Electronic competition chair		More ergonomic , comfortable
Special shape		Good looking appearance, more diverse designs
Wheelchair		light It can be moved without occupying space
Sofa, soft chair		Comfortable Relax

Change its wide (fold or else)		It can be used by patients of different weight
Improve		
Add track (head)		Movable, variable angle, height
Separate foot pads		Keep feet from moving
Add buttons		Add functions (such as playing games, expressing feelings when inconvenient)

Add wheel and handrails		It can move Add handrails at the back
Streamline & support		More comfortable and ergonomic The current sedentary may be tired, blood circulation is not smooth
Add-on attachment		
The device on the ground		The device on the ground can lift the wheelchair
Music playing device		Music playing
An added screen		An added screen that can watch TV

Handle, keyboard, mouse		Game Playing
Tell the weight		Without stigma to talking about the weight

8.3 Talk with the bariatric dentist

Dental chair is a special medical equipment. Contacting with dentist is a key step to obtain usability information. For the reason of the epidemic, Dr. Kwasnicki Andrew of Liverpool special clinic was very busy during this period. Although my expert Isobel tried to contact him many times at the beginning of the project, we did not have a video conference with him until January 14, 2021. He had provided me with a lot of valuable information as below.

For the process of treatment, Andrew pointed out that he was just as reluctant to discuss the topic of weight as the patient. It's embarrassing for both parties, even though sometimes they have to ask, "how much do you weigh?". Their special clinic won't use bariatric dental chair because of the price. If needed, they will borrow one from a major hospital. The use of wheelchair platform with benches was a cost-effective method, and the trolley was also used in the treatment process. If the patient weighs more than 34 stone, they will not be able to walk and will have to move with the help of a wheelchair or trolley. In this case, it is unreasonable to move them to the dental chair.

As for the number of users, Andrew said it's a very small number. His clinic received an average of 10 referrals a month. About 10-15 years earlier, the majority of citizens in the United Kingdom weighed less than 22 stone, and the highest weight limit for dental chairs was 28 stone. That is to say, at that time, the chair covered almost all the people. With the rise of obesity, certain patients now meet the weight limit and must be referred to specialized clinics. Until now, the majority of patients weighed less than 32 stone, and there is a niche in the

28 to 32 stone population.

Additionally, Andrew noted that the cost efficiency of dental chairs designed specifically for obese patients is significantly lower than that of benches. Design Specific dental practitioners account for less than 5% of dental practitioners. Other companies sell less.

Since I had progressed to the concept generation level by the time I spoke with Andrew. I told him about a few of my thoughts. Andrew endorsed the concept of making the dental chair foldable to accommodate patients of all sizes and recommended that I concentrate on the market below 32 stone. It also influenced my subsequent decision.

9 Decision-making: Concept evaluation and selection

9.1 Concept evaluation

The decision-making matrix is used for concept evaluation. This is a scoring matrix, also known as Pugh matrix analysis. It assists in determining which programs or future alternatives are more critical or superior. The value of the parameters in this score is neglected in this table since certain functions might be critical in one module but not in another. For instance, if I consider the criteria of "headrest position," it is unjust that the option emphasizing headrest design receives a high score while the option emphasizing entertainment feature receives a low score. They do not fall under the same group and thus cannot be equally compared using the same criterion. Since the project did not define the type of product, suggestions for improving various components were made concurrently. As a result, I shortened this table for reference purposes and will not use any of the top ratings. Other than that, I choose the three groups with the highest relative rankings. The relation is reasonably equal under the same group.

Table 9.1.1 Decision Making - Decision-making matrix

	Criteria												
Problems	Large Size	Sufficient Support	Head position	Ergonomics	Ease Access	Stability	Safety	Aesthetic	normal patients	Tell the weight	Satisfaction	Low cost	**Totals**
bed-like chair	5	3	0	3	3	3	1	3	0	0	3	2	26
Electronic competition chair	2	5	3	5	3	5	3	4	0	0	1	5	36
Special shape	4	4	2	4	4	3	3	5	0	0	4	5	38
wheelchair	2	4	3	3	5	5	5	1	0	0	1	3	32
Sofa, soft chair	4	4	1	2	3	2	1	3	0	0	3	2	25
change its wide	5	5	2	3	3	3	3	3	5	0	2	5	39
Add track（head）	0	3	5	5	0	5	5	3	0	0	1	5	32
Separate foot pads	0	3	0	5	0	5	4	3	0	0	1	3	24
Add buttons	0	0	0	0	0	0	0	1	0	0	5	2	8
Add wheel and handrails	0	0	0	3	5	3	3	1	0	0	1	4	20
Streamline & support	1	5	3	5	0	3	5	5	0	0	1	3	31
The device on the ground	0	0	3	3	5	3	4	3	0	0	0	4	25
Music playing device	0	0	0	0	0	0	0	5	5	0	5	3	18
An added screen	0	0	0	0	0	0	0	5	5	0	5	5	20
Handle, keyboard, mouse	0	0	0	0	0	0	0	5	5	0	5	3	18
Tell the weight	0	0	0	0	0	5	5	0	5	5	5	5	30

Table 9.1.2 Decision Making – Decision-making matrix results

	Criteria												
Problems	Large Size	Sufficient	Head posi	Ergonomi	Ease Acce	Stability	Safety	Aesthetic	normal pa	Tell the w	Satisfactio	Low cost	**Totals**
change its wide	5	5	2	3	3	3	3	3	5	0	2	5	39
Special shape	4	4	2	4	4	3	3	5	0	0	4	5	38
Electronic competition chai	2	5	3	5	3	5	3	4	0	0	1	5	36
wheelchair	2	4	3	3	5	5	5	1	0	0	1	3	32
bed-like chair	5	3	0	3	3	3	1	3	0	0	3	2	26
Sofa, soft chair	4	4	1	2	3	2	1	3	0	0	3	2	25

	Criteria												
Problems	Large Size	Sufficient	Head posi	Ergonomi	Ease Acce	Stability	Safety	Aesthetic	normal pa	Tell the w	Satisfactio	Low cost	**Totals**
Add track（head）	0	3	5	5	0	5	5	3	0	0	1	5	32
Streamline & support	1	5	3	5	0	3	5	5	0	0	1	3	31
Separate foot pads	0	3	0	5	0	5	4	3	0	0	1	3	24
Add wheel and handrails	0	0	0	3	5	3	3	1	0	0	1	4	20
Add buttons	0	0	0	0	0	0	0	1	0	0	5	2	8

	Criteria												
Problems	Large Size	Sufficient	Head posi	Ergonomi	Ease Acce	Stability	Safety	Aesthetic	normal pa	Tell the w	Satisfactio	Low cost	**Totals**
Tell the weight	0	0	0	0	0	5	5	0	5	5	5	5	30
The device on the ground	0	0	3	3	5	3	4	3	0	0	0	4	25
An added screen	0	0	0	0	0	0	0	5	5	0	5	5	20
Music playing device	0	0	0	0	0	0	0	5	5	0	5	3	18
Handle, keyboard, mouse	0	0	0	0	0	0	0	5	5	0	5	3	18

According to the results, three specific design problems are proposed:

1. How might we design a dental chair that can change its width so that people of all weights can use it?

2. How might we redesign the headrest of dental chair produced by design specific, including usability, position, function and ergonomics?

3. How might we design a device to hold and lift a wheelchair so that patients can get oral care in wheelchairs?

9.2 Concept selection

The designer has several reflections in response to the preceding three questions. In regards to the third idea, the system would be a movable lifting device or a floor modification. Mobile devices have appeared in the market, and there is little room for improvement. If the floor is rebuilt and a system is added under it, a structural issue arises that is incompatible with the specifications of industrial design projects; therefore, this choice is initially ruled out.

The remaining two ideas are sketched. Figure 9.1.1 shows the exploration of adjustable headrests, including different support shapes and link structures. Figure 9.1.2 shows the idea of a folding chair. After the simplification of the existing dental chair, the improved design of the backrest, up and down movement, and armrest is proposed.

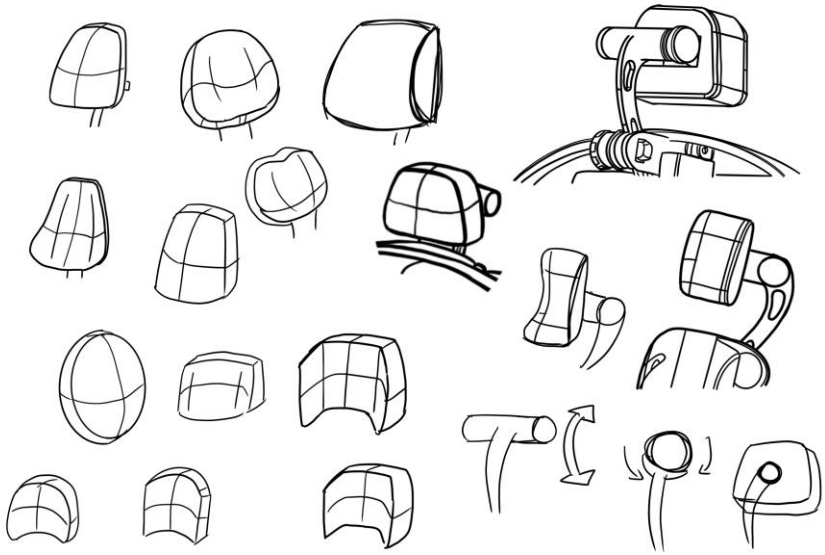


Figure 9.2.1: Sketch - adjustable headrests

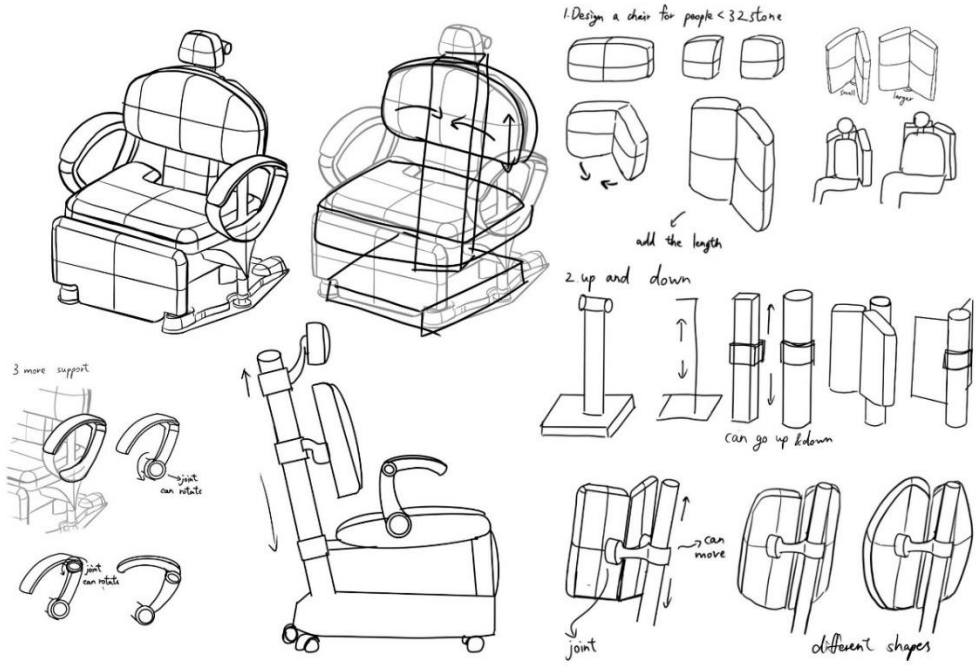


Figure 9.2.2: Sketch - folding chair

9.3 Reason to focus on the backrest

Since we couldn't contact Kwasnicki Andrew, a special clinic dentist, after January 14, the designer e-mailed Nicholas Longridge, a general clinic dentist, and contacted him. He was interested in the idea of folding chairs and praised it as a good idea. Combined with the advice of the project supervisor and expert,

the idea of designing a dental chair that can change its width was finally adopted.

The advantage:

- It can simplify the patient pathways, make most patients who need special care continue to use mainstream dental services, and reduce the pressure of special care services
- Better patient experience is provided. Patients will have easier access to care without the embarrassment and stigma of going to a special clinic.

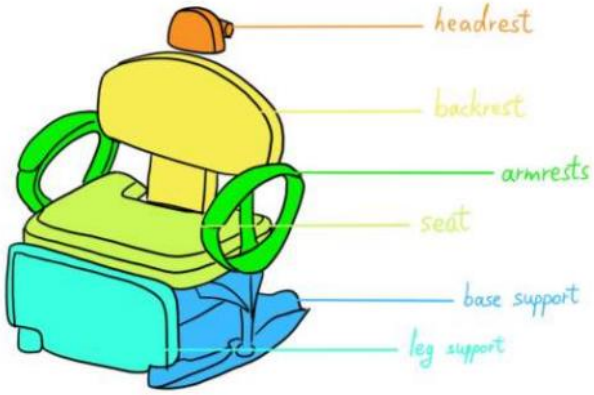


Figure 9.3.1: Different parts of a dental chair

Figure 9.3.1 shows the different parts of the dental chair. The project will redesign an adjustable bariatric dental chair so that it can be used by mainstream patients, focusing on the backrest.

The reason to focus on the backrest:

The backrest is the most critical part to make adjustable because:

1. It is vital for the dentist. They need to easily access the patient's mouth - if the backrest is too wide the patient is difficult to reach, which may cause inefficiency and ergonomic issues.

2. It is arguably the most difficult part to make adjustable. Detailing the backrest is important in proving the viability of the rest of the chair.

3. The backrest of a dental chair is subject to more force than the backrest of most chairs since the patient leans back with their weight on it and the patient's back and chair back will be in contact for a long time.

10 Embodiment Design

Embodiment design (Pahl and Beitz, 1996) is a procedure that occurs during the design phase. The design process begins with the working framework or definition of technological goods and progresses according to technical and economic requirements and additional details before the resulting comprehensive design can be specifically translated into development. It can be divided into three stages: product architecture, design configuration, and parametric design.

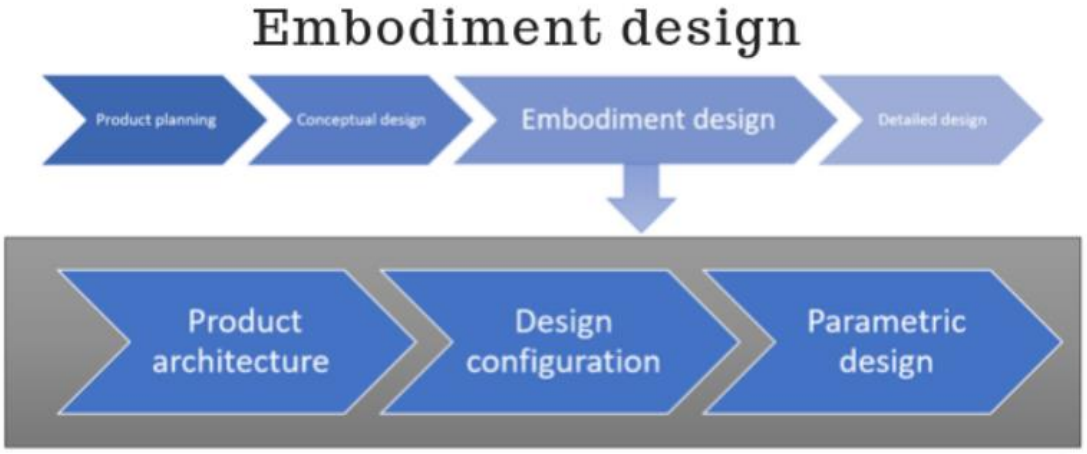


Figure 10.1: Embodiment design stage (Pahl and Beitz, 1996)

10.1 Product architecture

Product architecture illustrates how the product's functional components are partitioned. They work together to form a whole.In figure 10.1.1, the backrest is divided into three main systems: energy supply system, regulation system and support system.

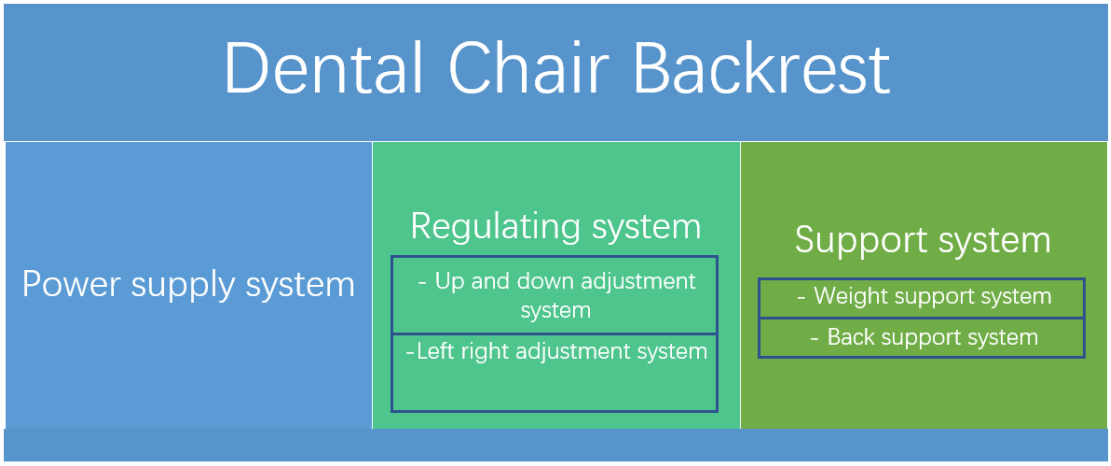


Figure 10.1.1: Product architecture

In the energy supply system, the dental chair is connected to the clinic power supply and powered by the office voltage. In the regulation system, it is divided into up and down regulation system and left and right regulation system. The up and down adjustment system allows the back to be adjusted according to the height of the user. The left and right adjustment system allows the back to be adjusted in width according to the user's weight. Support system is divided into weight support system and back support system. The weight support system is the load-bearing function of the whole structure to ensure the stability and safety of the product. The back support system is the ergonomic comfort, which provides the support area and support mode for the back.

10.2 Design configuration

The shape and general dimensions of the design configuration are determined by the components specified in the design configuration. It establishes the fundamental framework for the operation of the component and product method, including the initial collection of components, models, and component sizes.
Figure 10.2.1 shows the basic framework of the product, and then a rough model was made for discussion.

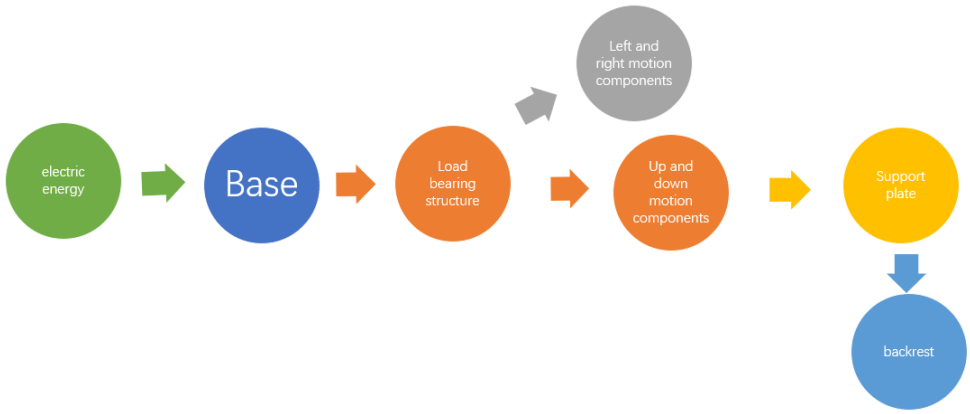


Figure 10.2.1: Design configuration

10.3 Draft 3D model

A framework model was created to facilitate future dialogue. To prepare for the next appointment with the dentist, some simple images containing the previously mentioned contents were produced. Figure 10.3.1 shows the overall structure of the dental chair and the backrest to be concerned.

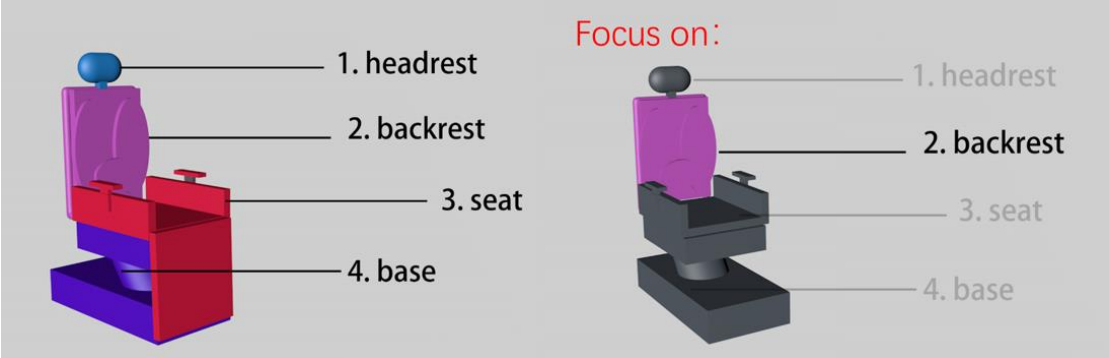


Figure 10.3.1: Draft 3D model - The overall structure of the dental chair and the backrest to be concerned

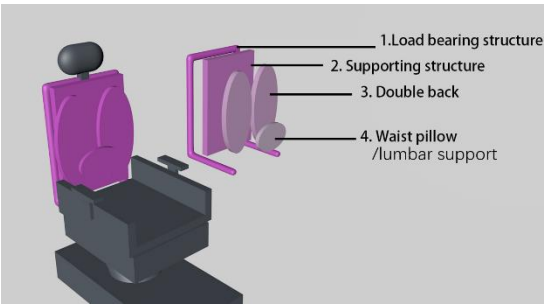


Figure 10.3.2 describes the structure of the back, including four parts. A load-bearing structure connected to the base of the dental chair, a support structure connecting the load-bearing structure and the back, a double back design in contact with the back, and a lumbar support structure.

Figure 10.3.2: Draft 3D model - The structure of the backrest

Figure 10.3.3 shows the materials expected to be used. The load-bearing structure is made of stainless steel, the support structure is made of plastic or hard sponge, the back cushion is made of mesh structure of similar products, and the lumbar support is filled with soft cotton.

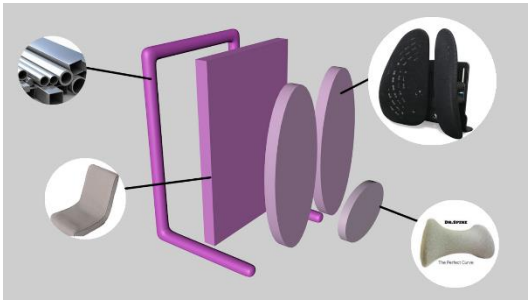


Figure 10.3.3: Draft 3D model - Materials expected to be used

Figure 10.3.4 illustrates how the chair can be adjusted to accommodate individuals of varying weights. Two separate seatbacks can be opened outward to accommodate heavier patients. Since the dental chair is a whole unit, the design of the seat rest is also taken into account. As shown in the illustration, the seat can be opened 90 degrees to accommodate the width of the chair back. The armrest is an adjustable angle design that is fixed to the seat or base, ensuring that the armrest plane is always level.

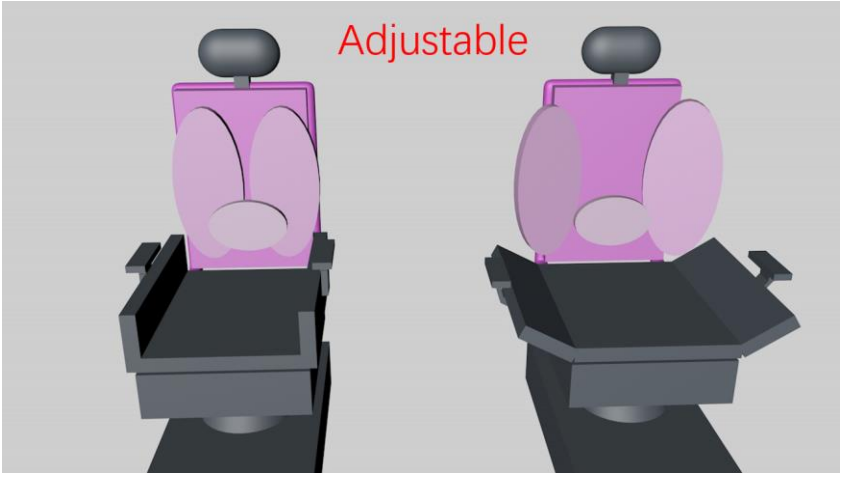


Figure 10.3.4: Draft 3D model - Adjustable design

10.4 Parametric design

The primary objective of parametric design is to generate the optimal design in terms of both efficiency and cost. It entails establishing measurements and tolerances in order to optimize consistency and efficiency. Given the dental chair's engineering specifications and criteria as a piece of specialist medical equipment, it would be constructed using the "Ergonomic requirements for dental equipment" (Hokwerda, et al., 2006) as a reference.

10.4.1 Reason to use the guidelines

The criteria for standardizing and using dental instruments have the following advantages:

1. Comply with EU legislation and regulations governing the CE mark, so that equipment designs and manufacturers can follow applicable safety requirements without endangering the health of users.
2. Ascertain the equipment conforms to ISO and Cen requirements within the scope of new standards
3. Make a thorough selection of dental equipment.
4. Ensure the health and well-being of dental students and dentists
5. Provide user-friendly equipment, safeguarding the health and welfare of workers in order to shield them from and avoid workplace hazards

10.4.2 Dimension of the product

According to the Ergonomic requirements for dental equipment (Hokwerda, et al., 2006), the minimum length of the back of the patient's chair that will accommodate the patient's shoulder without obstructing the dentist is 40.9 =

41 cm (shoulder length 53.9 minus approximately 13 cm)). About 3 cm at the shoulder's tip, 44 cm in the center of the top to completely accommodate the shoulder and connector. It is important to attach the shoulder support and the lower part of the neck in order for the patient to relax and achieve the optimal mouth opening.

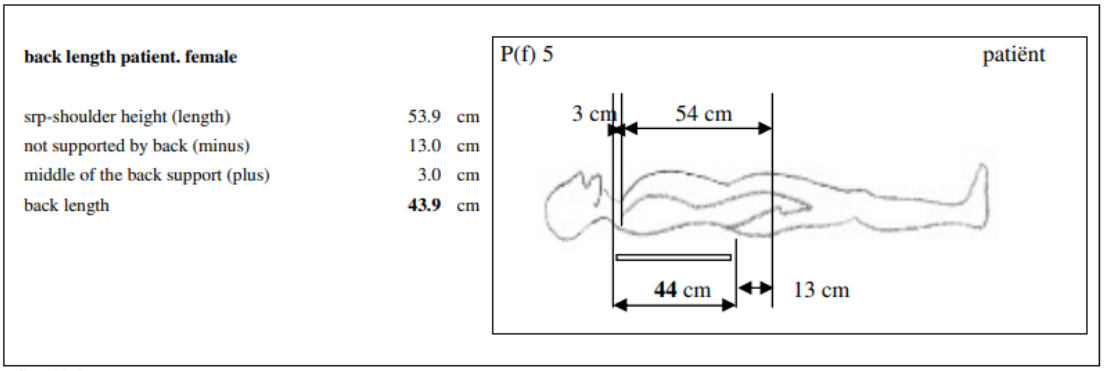


Figure 10.4.2.1: the minimum length of the back of the patient's chair (Hokwerda, et al., 2006)

The diameter of the top of the backside used to protect the shoulder, without irritating the dentist, is 42 cm. Two conditions must be met by this data: 1. As far as possible, support the patient's shoulder and do not obstruct the dentist's approach to the patient. 2. The diameter of the rear side at the tip is 42 cm, causing the patient to shift further to the left and right in order to bend the head back.

48 cm is the diameter of the back section that the elbow must support (56 cm considering the width of the upper body and elbow). The dentist must, however, be able to keep the work area approximately 27 cm away from the upper body without breaking contact with the upper arm and lower body. While patients with greater height could be taller, using 48 cm as the width of the patient's chair back is fair. As a continuation of the back, the patient's elbow should be held on the bending elbow braces on both sides. Both brackets are 11cm wide, which enables the elbow to be easily held at a certain distance from the upper body without slipping. The help must be at least 15 cm long in order to completely surround the elbow. The backrest's bottom section can be shrunk to within 43cm of the seat diameter.

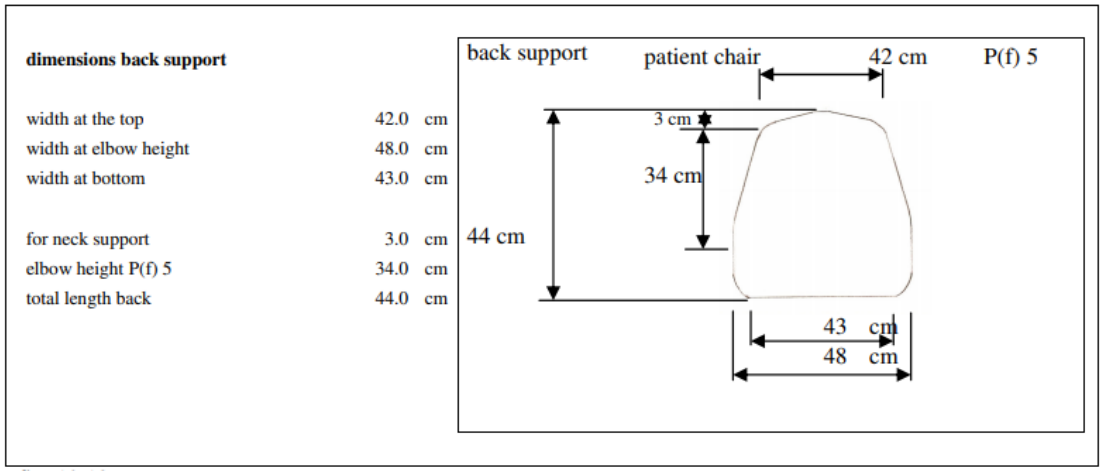


Figure 10.4.2.2: Dimensions back support - 1 (Hokwerda, et al., 2006)

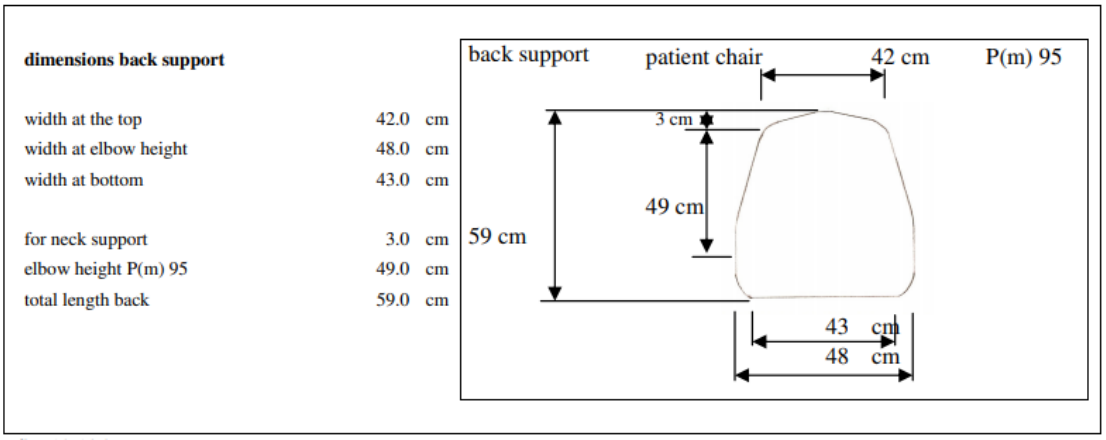


Figure 10.4.2.3: Dimensions back support - 2 (Hokwerda, et al., 2006)

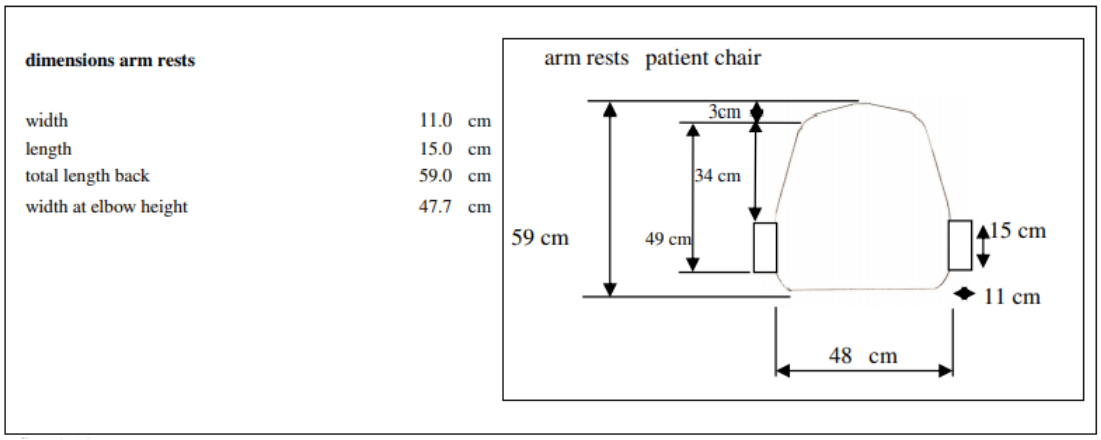


Figure 10.4.2.4: Dimensions back support - 3 (Hokwerda, et al., 2006)

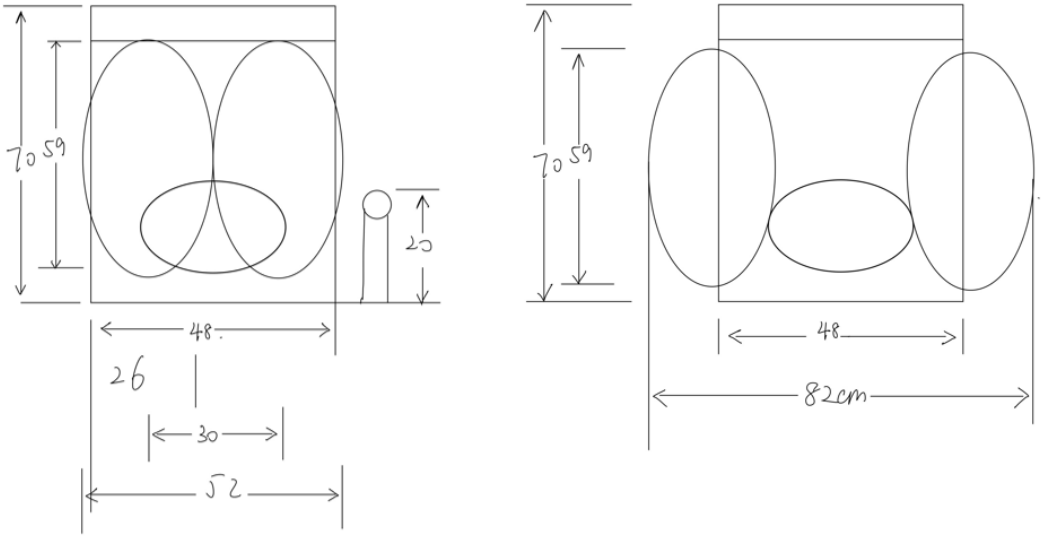


Figure 10.4.2.5: Dimensions back support –sketch draft

Based on the above data, the size of the product is specified. Each piece of the double dorsal structure is 59 cm long and 48 cm wide. The bearing structure is 70cm long and 48cm wide. When the back is the minimum width, the maximum length is 52cm (26 * 2). When the back reaches the maximum width, it can reach 82cm theoretically.

Based on the data of adult men's clothes (XXXL), assuming that the circumference is 135cm and the waist is an ellipse with the ratio of length to width of 2:1, the length and diameter of the ellipse is 52.53cm. It is far below the theoretical maximum width of 82cm. As a result, the overall size for the product's intended target community exceeded the required size. Following that, the designer would discuss the most suitable range with the dentist.

Men's Size Charts

Men's General Apparel Size Chart

Size	Chest	Waist	Inseam
S	35"-37" (89 cm - 94 cm)	29"-31" (74 cm - 79 cm)	30.75" (78.1 cm)
M	38"-40" (95 cm - 102 cm)	32"-34" (80 cm - 86 cm)	31" (78.7 cm)
L	41"-43" (103 cm - 109 cm)	35"-36" (87 cm - 91 cm)	32" (81 cm)
XL	44"-46" (110 cm - 117 cm)	37"-38" (92 cm - 97 cm)	33" (83 cm)
XXL	47"-49" (118 cm - 124 cm)	39"-40" (98 cm - 102 cm)	34" (86 cm)
XXXL	50"-53" (125 cm - 135 cm)	41"-43" (103 cm - 109 cm)	34.75" (88 cm)

Figure 10.4.2.6: Men's size charts (Warehouse, 2021)

10.5 Talk with the normal care dentist

On March 18, 2021, I had a video conference with dentist Nicholas Longridge, expert Isobel Leason. I presented him with the analysis and models so far, and he offered the following suggestions:

1. The movable double back style was the wisest and preferred part for him.
2. The chair's base might be smaller, similar to an ordinary chair; the builder could also point to a dental chair with a particular style. When the patient lay in the chair, the lower leg and thigh were maintained at 90 degrees, which made sitting and standing more comfortable.
3. Consideration of the minimum distance was superfluous. The current norm was adequate. The clinic had specialized instruments for infants.
4. A overall width of 68cm was recommended. Given the adjustability of comparable goods, this size was also conveniently to made.
5. It is necessary to understand the engineering aspect. The weakest component could not carry an excessive amount of weight.

As a result, the double back architecture is preserved and improved upon. The chair back's full width is set at 68cm, and the left and right sides can be changed by 8cm each. The minimum diameter is unaffected. The survey of engineering structures will be discussed in greater detail later.

11 Virtual Prototype

11.1 Product iteration

The product is constructed in stages after the size is determined. To begin, a frame of the same size is constructed (replaced by a cube). Then, using the cube as a guide, change the shape until it conforms to the desired shape.

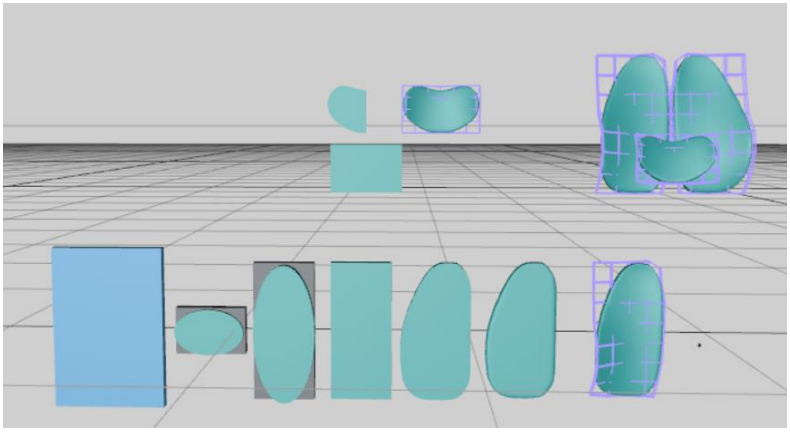
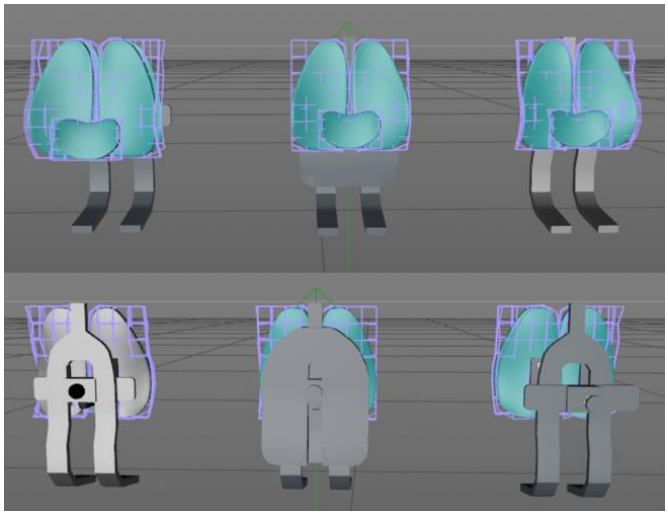


Figure 11.1.1: Process of making the model



The first-generation model's load-bearing structure is a square steel bar system with manual control. After debate and consideration, it was determined that the square cross-section is easier to break and has a higher production cost than the cubic cross-section. As a result, circular cutting surfaces were adopted.

Figure 11.1.2: Iteration of the product

If the product is manually operated, the patient has no opportunity to adapt when laying on his back. Additionally, the conventional dental chair is operated by a ground control board that contains simple circuit control adjustments. In general, although the price would rise, the addition of an electric control significantly improves the user experience.
In terms of the casing, for ease of repair, a shell that completely encases the internal structure is the best option. However, similar products do not use the shell. When considering product repair, the object of maintenance can be accomplished by providing for the disassembly and washing of individual components, or by replacing them entirely. Therefore, the product will not use the shell.

11.2 Final rendering

This year's online course prevented the production of real models, so the virtual prototype was made and rendered in 3D modeling software (C4D & 3D Max). Figure 11.1 shows the front view rendering effect of the final model.

Figure 11.2.1: Virtual Prototype - the front view

Figure 11.2.2 shows the models with different angles, including oblique front, side, oblique rear and back.

Figure 11.2.2: Virtual Prototype - different views

If the product is placed in a real use scene, its effect is shown in Figure 11.2.3.

Figure 11.2.3: Virtual Prototype - visual effects

12 Detail Design

12.1 Engineering analysis

The force analysis is carried out in the force simulator of Creo. Through the simulation of 3D model, the required Young's modulus and allowable stress can be obtained. Figure 12.1.1, 12.1.2 and 12.1.3 show the stress analysis results of the main load-bearing structure of the product.

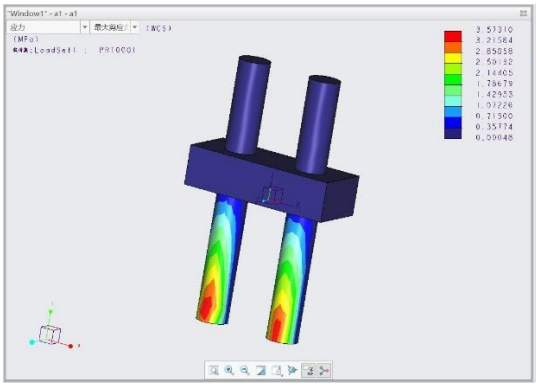


Figure 12.1.1: Force analysis - Shear stress

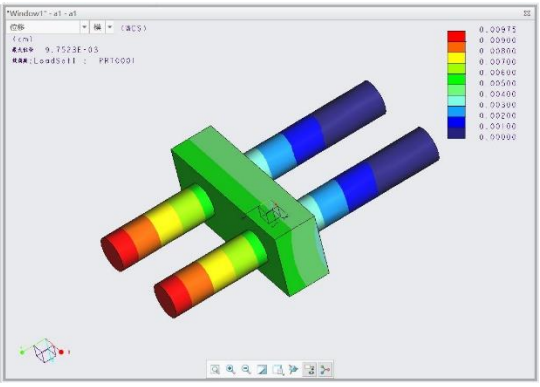


Figure 12.1.2: Force analysis - Displacement

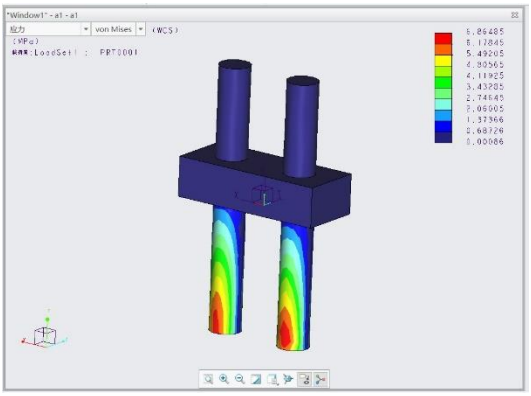


Figure 12.1.3: Force analysis - Stress

The results show that the maximum allowable Shear stress of the material is 3.57 MPa (when the maximum load is 32 stone), the maximum displacement is 0.0098 cm, and the maximum stress is 6.86 MPa.
Consider the table of design material properties for structural steel (EurocodeApplied, 2021), the tension is equal to the pressure times the load factor.

$$\mathrm{F} = \mathrm{P} \times \text{load factor} \times \mathrm{r}$$

$$\sigma = \frac{F}{d}$$

Where F represents tension, P represents pressure, R represents radius, D represents wall thickness.

Then

$$d \geq P \times 1.4 \times \frac{r}{\sigma}$$

$$\frac{r}{d} \leq 22.37$$

After referring to the rules commonly used in factories, the round pipe with a radius of 25 mm and a wall thickness of 1.5 mm was selected to meet the pressure requirements

12.2 Technical drawing

In addition to the parts that can be purchased directly, engineering drawings are made and provided. It should be noted that parts 2 and 3 need to be further processed because they have radians. The engineering drawing of these two parts is only for the reference of dimension.
They can be found in the appendix.

12.3 Advantages of double back

Dr. Matthias Brünig (DUOREST, 2021), a German physicist, discovered that if a person sits on a chair for an extended period of time, he will get back pain as a result of excessive pressure on his spine and muscles. He noted that the human body is shaped like a flat melon. The breast and crotch are generously sized, while the waist is slim. It is a triangular double S shape in three dimensions. Not only is the back spine's curve S-shaped, but it is also S-shaped in all directions from the back to both sides of the body. Even if the design of standard single back chairs accommodates the human back's S-shaped curvature, they can only create a sense of fit in one direction. There is little contact with the rest of the body, and they are incapable of supporting the body upright. As a result, after prolonged sitting, lumbar and cervical pain will occur.

Figure 12.3.1: Similar product example

The stress point on a double back chair is much different from the stress point on a single back chair. The double back chair's design distributes pressure from the waist and spine to the left and right latissimus muscles, resulting in a hand-like supporting force. Rather than just supporting the user's lumbar vertebrae, it's as if a pair of large hands are supporting the entire back.

12.4 Function design

12.4.1 Adjustable width and height

When the patients of ordinary shape use the dental chair, the back of the chair is in the initial state, with the narrowest width and the shortest height. With the increase of body weight, each back can move 8 cm outward, a total of 16 cm, and the longest width is 68 cm. Lumbar support can be adjusted up and down 5cm manually to achieve the most comfortable position of patients. Because the two backs drag the latissimus muscle of the human body, and do not take the spine as the stress point, the feeling of use will not be affected when there is a gap in the middle. Lumbar support also provides greater contact area for patients. The entire back can be moved 5cm up together to ensure that there is no too much space between the head and shoulder.

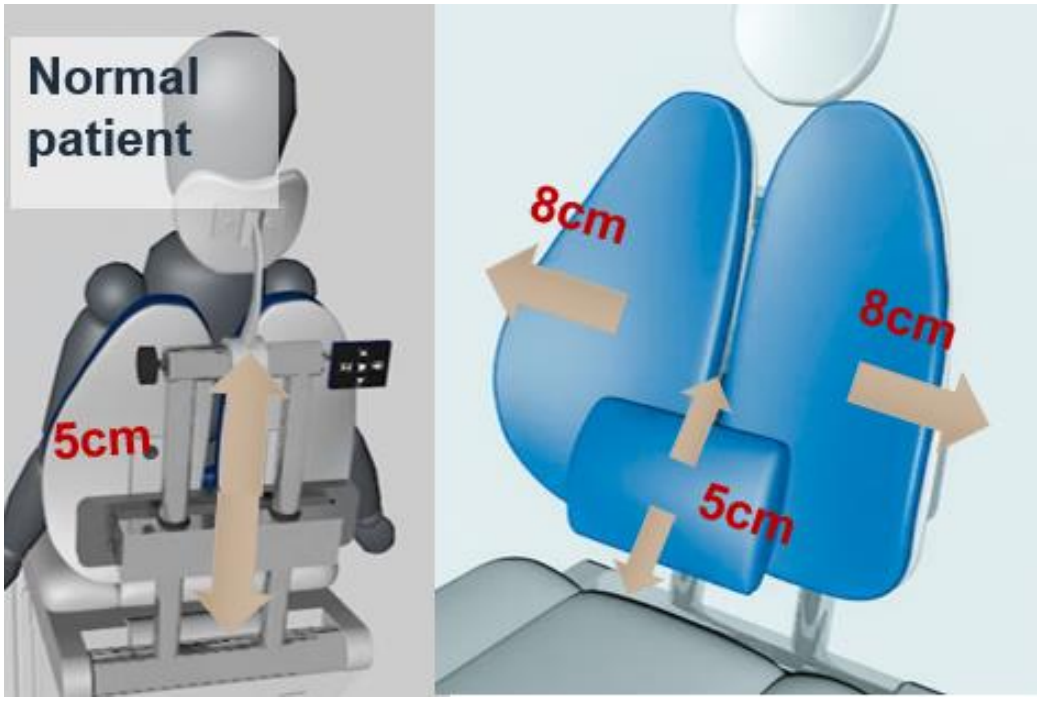


Figure 12.4.1.1: Use of the product - Normal patient

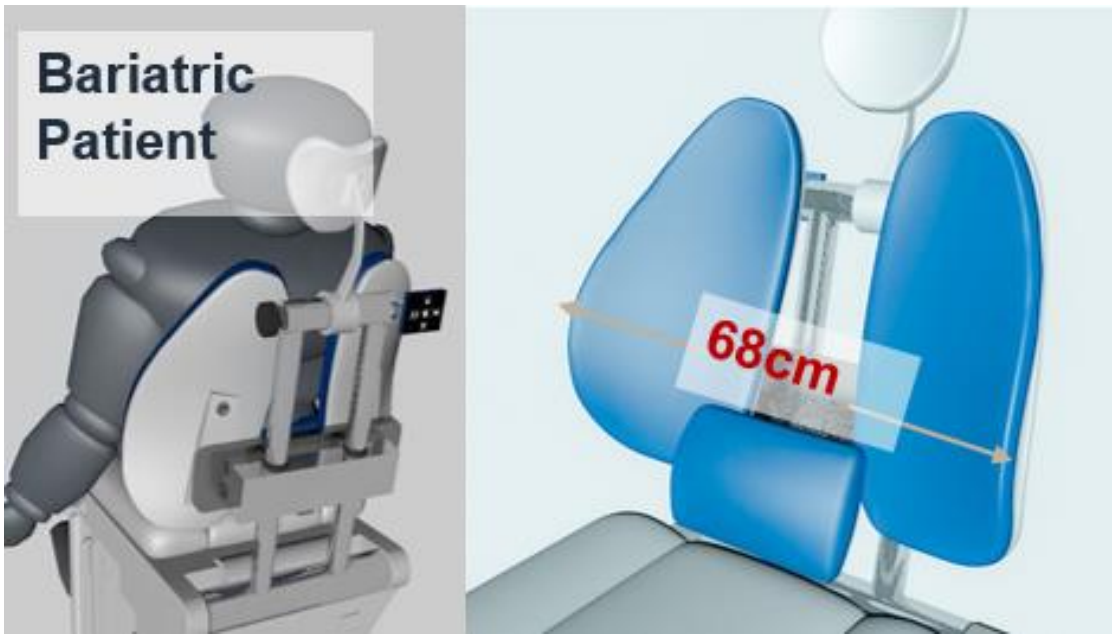


Figure 12.4.1.2: Use of the product - Bariatric patient

12.4.2 Move with the body

The two independently designed seatbacks may adjust to the movement of the back, always fitting the back curve, and dispersing the upper body's strain on the spine and lumbar spine. This design eliminates discomfort caused by small patient movement.

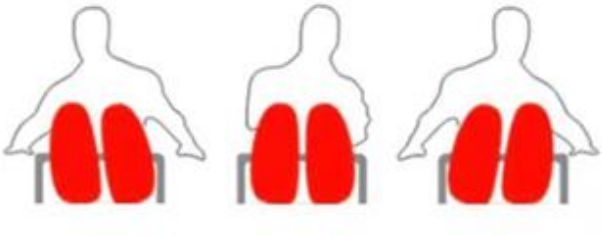


Figure 12.4.2.1: Seatbacks may adjust to the movement of the back

12.4.3 Simple Interface

A traditional dentist chair is operated through a foot pedal, whereas some obese dental chairs have an operation interface hidden underneath the armrest. Typically, chairs have two distinct foot pedals - one is a large plate that regulates the power to the handpieces; the other pedal is a small plate that regulates the power to the armrests. This is typically also where the water off/on switch is located. The second pedal, which is occasionally a foot lever attached to the chair, controls the chair's height, depth, upright, and supine positions. It may become quite perplexing if this pedal included additional controls. Regarding the back rest, the dentist suggests that buttons on the shoulder or head rest might work, as they are often manipulated manually on a majority of chairs.

Figure 12.4.3.1: Operation device for bariatric dental chair (Duorest, 2021)

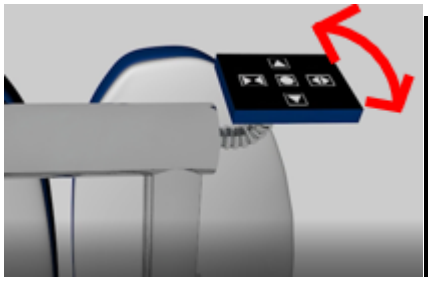


Figure 12.4.3.2: Position of the Control Device

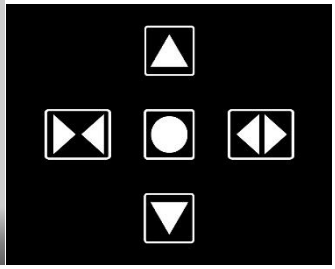


Figure 12.4.3.3: User interface

Consider the situation in which the doctor is seated behind the patient (near the shoulder). It is connected to a rotatable tube that allows it to be contacted in two different operating states: upright and lying. The button was designed to be simplified. The reset button is located in the center. When pressed, the chair reverts to its original configuration (narrowest and shortest). The upper and lower buttons adjust the overall seat back's height, while the left and right

buttons adjust the seat back's width.

12.5 Electronic components

The following table 12.5.1 shows how the dental chair control chip works, using the common dental chair built-in control chip, and referring to the A-dec control system (A-dec, 2021).

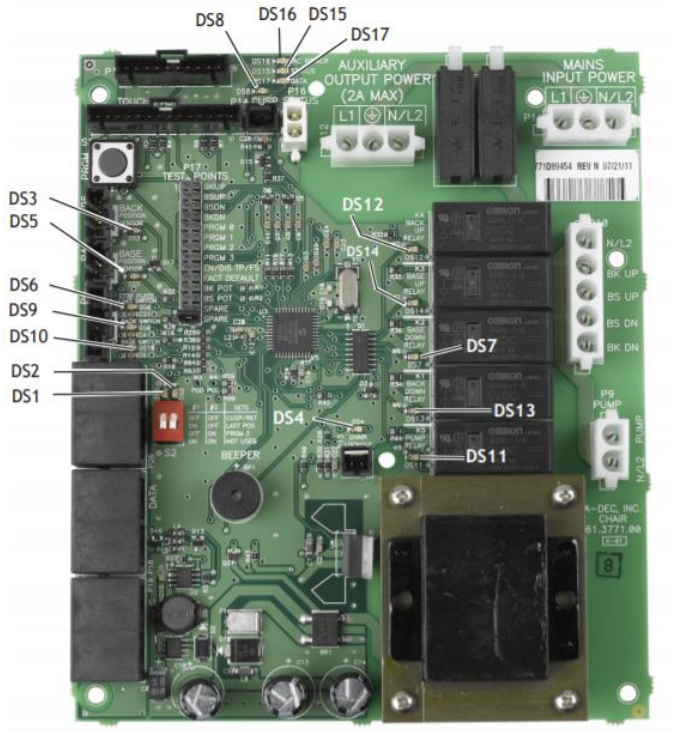


Figure 12.5.1: Picture of circuit board

Table 12.5.1: Circuit board

Name	Description
DS16	Power and line voltage on / off
DS15	System power on indication, normal / abnormal operation
DS17	Check whether it is connected to DCS information Check whether DSC information is valid
DS6	Stop plate limit switch control
DS54	Dental chair locked
DS3 and DS5	When the back or seat of the treatment chair is active, the potentiometer works
DS7, DS13, DS12, DS14	Relay off / on
DS8	Spittoon switch
DS9	Seat back up limit switch
DS10	Seat lift limit switch
DS11	Relay switch
DS1, DS2	Gear function selection

12.3 Material and Manufacturing

This part will introduce the selection of material and manufacturing method of main parts (that cannot be purchased directly).

12.3.1 lumbar support

Lumbar support is not the load-bearing component; it exists to instill confidence in the user's ability to use the device. Before they sit in a chair for the first time, individuals always have reservations about the gap in the middle. While lumbar support does not alter the latissimus muscle's qualities as the primary stress point, it can spread a little portion of the strain, which can help people feel more comfortable to a certain amount. It is lined in soft cotton and does not increase the waist burden.

12.3.2 Double back

The back is filled with stereotyped sponge, a kind of high-quality sponge, which is usually used in game-chairs. Compared with the traditional sponge, it has higher durability and longer life. The stereotyped sponge is twice as elastic as 50 density sponge and has a third longer life. There are five steps to make stereotyped sponge: mold opening, material injection, foaming, demoulding, and trimming. It costs 1 / 4 more than 50 density sponge (excluding mold opening price).

Figure 12.3.2.1: Stereotyped sponge - Manufacturing diagram

12.3.3 Surface fabric

The surface material of the dental chair should be as similar as feasible to that of the present dental chair, and the color should also be classic blue. Here, an outstanding partner is provided as an option. As a provider of dental chair textiles, Ultrafabricsinc (2021) offers a high-performance fabric made of robust and flexible polyurethane materials that are meant to withstand the rigors of dentistry and healthcare environments. Its remarkable qualities include excellent hydrolysis, outstanding durability, liquid and moisture resistance, skin compatibility, allergy, and PVC-free construction, and EPA-certified antimicrobial protection (in selected styles).

12.3.4 ABS fireproof plastic connector

In recent years, ABS plastic has become the first choice for several dental chair manufacturers. It has the characteristics of high impact resistance, strength and rigidity, as well as special chemical and wear resistance. As medical equipment, fire resistance is also a point to be considered. For example, the flame retardant ABS material provided by Eagleplastics (2021), with excellent flame retardant performance certification UL94 VO classification, is a good choice.

12.3.5 Buffer column

In order to make the seat back fit the back adjustment within a certain range, the soft plastic buffer column is used to connect the back and the mobile device. It can be deformed in a small range and keep the original shape without pressure.

12.3.6 Stainless steel support

Due to the fact that the rear structure does not come into direct contact with the skin, 304 / 304L steel is frequently utilized in medical equipment. It is austenitic and is appropriate for framing, bases, brackets, bodies, and guards. They offer superior corrosion resistance, making them ideal for interior applications. However, with the use of an active cleaning technique, they may be applied outdoors or in environments exhibiting evidence of tarnishing or pitting over time (Penta, 2021).

304 – 0.08% 304-0.08 %
304L – 0.03% 304L-0.03%

304 stainless steel is the most widely used kind of stainless steel in the world. It is frequently used in round bar, sheet, plate, and some limited dimension forged bar, as well as tube, angle, and channel sections.

12.4 Part list and Bill of Materials

12.4.1 Part list

Figure 12.4.1.1 shows the exploded view and detail of the part:

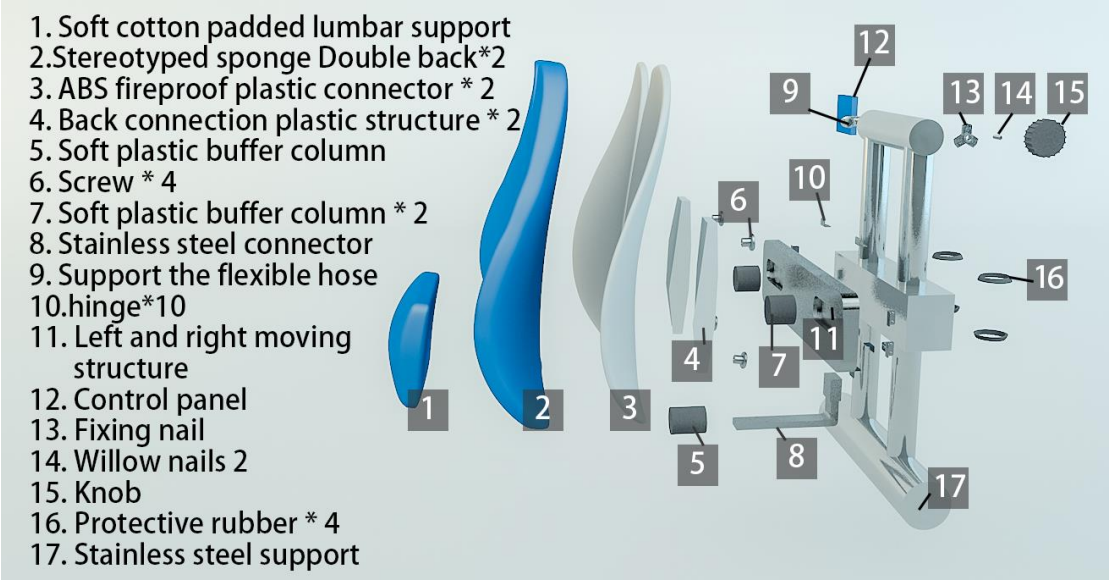
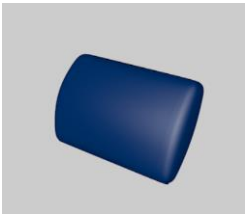


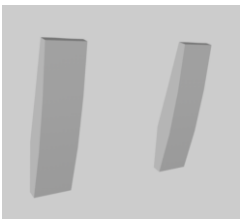
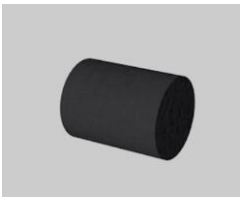
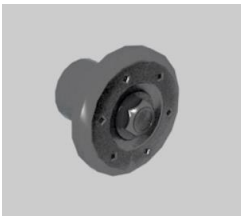
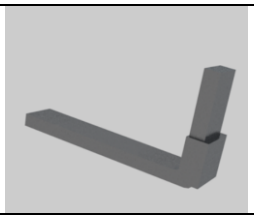
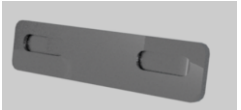
Figure 12.4.1.1: Exploded view and parts details

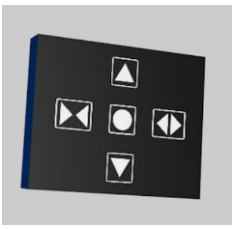
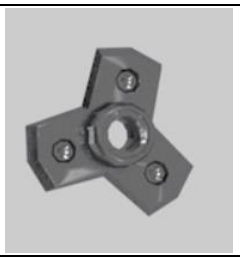
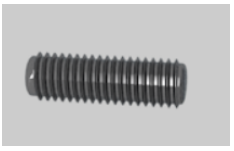
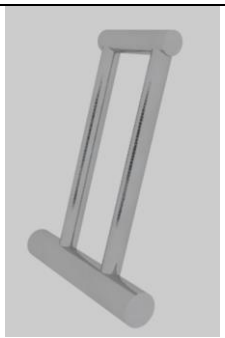
12.4.2 Bill of Materials

Table 12.4.2.1: Bill of Materials

Bill of Material

Product : Douback Dental Chair					Date:2021/5
Item #	**Picture**	**Qty**	**Name**	**Material**	**Source**
1		1	Lumbar support	Soft cotton	Manufacture
2		2	Double back	Stereotyped sponge	Manufacture
3		2	Double back connector	ABS fireproof plastic	Manufacture

4		2	Back connection structure	ABS plastic	Manufacture
5		1	buffer column-1	Soft plastic	Purchase
6		4	Screw	Steel	Purchase
7		2	buffer column-2	Soft plastic	Purchase
8		1	Lumbar support connector	ABS plastic	Manufacture
9		1	The flexible hose	Steel	Purchase
10		10	Hinge	Steel	Purchase
11		1	Left and right moving structure	ABS fireproof plastic	Manufacture

12		1	Control panel	Screen	Manufacture
13		1	Fixing nail	Steel	Purchase
14		2	Willow nails	Steel	Purchase
15		1	Knob	Rubber	Purchase
16		4	Protective rubber	Rubber	Manufacture
17		1	Bearing column	Stainless steel	Manufacture

12.5 Sustainable design

The sustainable design aims to minimize adverse effects on the environment, as well as the health and comfort of building inhabitants while optimizing building performance. Sustainability's fundamental goals are to limit nonrenewable resource use and to limit waste.

Life cycle assessment (LCA) (Ljungberg, 2007) is a technique for determining an object's influence on the environment, and it is also a highly popular form of evaluation. It will be used to assess a product's sustainability.
The product life cycle consists of five stages: raw material extraction, manufacturing & processing, transportation, usage & retail, and waste disposal. It includes four steps: definition of goal and scope, inventory analysis, impact assessment, and interpretation

Figure 12.5.1: Life cycle assessment (Ecochain, 2021)

12.5.1 Goal and scope

The first phase of the objective and scope life cycle analysis includes the determination of the basic framework of the whole research. The product will be evaluated according to the following aspects:

1. Raw materials for product production (Manufacturing)
2. Hardware components for product procurement
3. Product service life
4. Maintenance and replacement of products
5. Products and surrounding environment

12.5.2 Inventory analysis and impact assessment

The second phase will record everything that enters and exits the previously described system. The third phase will show their affects.

Table 12.5.2.1: Inventory analysis and impact assessment

Inputs	Outputs	Affects
Metal (steel, aluminum)	Steel	Waste discharge may occur in industrial metallurgy, such as sewage, harmful gases, etc. Waste steel also causes a waste of resources
Plastic	Plastic parts	Plastics are difficult to degrade, and when they are discarded, recycling

		becomes a problem. The extensive use of plastics accelerates white pollution.
Rubber	Knob	In the process of rubber production, there may be sewage and waste discharge, which pollutes the environment.
Fibre	textile	Cloth industry is a traditional type of light industry, which needs a lot of water, electricity and other resources.
Electric	Energy	In the process of power conversion, power grid transmission may lead to power loss. If the power station does not use clean energy, it will pollute the environment.
Water	Waste Water	Water is widely used in industrial production and is discharged as steam or sewage. A large amount of water also aggravates the problem of water shortage.

12.5.3 Interpretation

1. Raw materials for product production (Manufacturing)
Pollution throughout the raw materials processing process is unavoidable; the trick is to identify the suitable raw materials and manage pollution throughout the manufacturing process. Globalization of commerce enables producers to get the best raw materials from all around the globe. As a mature industrial product, dental chairs come with a plethora of pre-engineered manufacturing alternatives. The treatment of pollution requires a concerted effort on the part of society and government.

2. Hardware components for product procurement
In comparison to the dental chair's base, the back lacks a plethora of hardware features. It is controlled by the control panel and is linked to the central control chip. If it is not in use, it does not need replacement within five years. During maintenance, iterative products might be replaced.

3. Product service life
As an expensive piece of medical equipment, dental chairs have a service life of more than 10 years. The chair back's primary body is made of stainless steel, which has a longer life than a regular sponge. Stainless steel is also frequently utilized in the medical industry. Corrosion resistance enhances the product's longevity.

4. Maintenance and replacement of products
The product is composed of several components that are linked by screws or connections. It may be cleaned, maintained, or changed from various locations of the screw installation for the purpose of routine medical equipment maintenance. If a critical component fails, the cost and waste of replacing it are less than the cost and waste of upgrading the whole product.

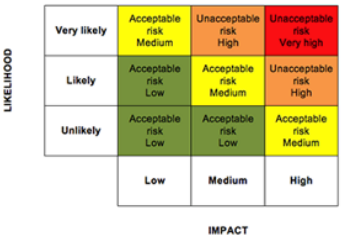
5. Products and surrounding environment
In a general dental clinic, a dental chair is installed. After scrapping, it shall be cleansed and damaged for safety. This portion is managed by another department, and the hospital may contract with outside vendors. In the general, medical equipment does not contribute to air or water pollution during its use and will be appropriately disposed of after scrapping.

12.6 Risk assessment

The potential safety hazards and their analysis are shown in the table 12.6.1 below.

Table 12.6.1: Risk assessment

Risk	possibility	Imapct	Score
Human – Illness, death, injury	Unlikely	High	
Operational – Disruption to supplies and operations	Likely	High	
Reputational – Loss of customer or employee confidence	Very Likely	Low	
Project – Going over budget	Likely	Low	
Financial – Business failure	Likely	High	
Technical –technical failure	Unlikely	Medium	
Natural – Weather, natural disasters, or disease	Unlikely	Low	
Structural – Dangerous chemicals, poor operation	Very Likely	High	



The following strategies are established in response to potential risks:

No gadget can provide 100 percent assurance of safety. If there are casualties as a result of instrument failure, the affected patients should be sent to the emergency department. This procedure may be completed quickly due to the close proximity of the regular dentistry clinic and emergency department. Then determine the root cause of the problem, notify the manufacturer, and perform any necessary maintenance or product updates.

Errors in operation might result in the instrument falling and being damaged. If the damage is the result of a physical accident (collision, collapse), determine if it affects the overall function and then replaces the damaged elements in the proper location.

Users' skepticism may be alleviated by genuine product usage. Prior to making touch with new objects, patients will always have concerns about whether the new equipment is superior to the old, which may be resolved by real usage.
We may seek government or social aid if we do not have sufficient finances for the project. The investment in medical projects may exceed the budget, and in the interest of security, alternative materials or suppliers may be explored.

The likelihood of a firm failing is rather remote. There are few rival items on the market at the moment, and demand for dental chairs is expanding as well. Natural calamities cannot be subjectively prevented. In the event of an earthquake, debris flow, tsunami, or other natural catastrophes, it is required to first ascertain if there are fatalities, then verify product inventories, dispose of reported waste items, request for financial assistance, or initiate an emergency plan.

Dental chairs used in dental clinics may expose patients to hazardous substances. Once someone has been harmed, they should be sent to the emergency department. It should be evaluated in advance whether to adopt standard specs and product settings that allow for mistakes.

13 Self-reflection

Final year design, as an application and challenge of university life, enables me to have more in-depth knowledge and experience of the design itself. Along with familiar design possibilities, user research, and market research techniques, I gained fresh perspectives, modeling approaches, sustainability analysis, and risk prediction abilities. This dental chair project is neither simple nor straightforward. From the beginning, I felt lost, anxious, and self-conscious in the introduction, but by the end, I was eager and happy to go on to the final design and completion of the final product. I learned a great deal and gained a great deal through this process. I'd want to express my gratitude to everyone that assisted me. Being able to create with Farnaz Nickpour is a valuable experience for me as a student and a priceless asset for me as a designer. Isobel leason, my expert, is an accomplished oral health designer. Her unmatched expertise in this sector enables me to create more effective medical gadgets. I appreciate the two dentists taking the time out of their busy schedules to answer my questions and provide important feedback on my ideas and goods. I am aware that due to the constraints imposed by present legislation and the environment, my plan cannot be implemented rapidly. Dental chairs are very intricate pieces of equipment. I concentrate only on the back of

the chair. While this is not a perfect solution, I hope that the concept of encouraging more individuals to utilize standard dental services inspires future design. I hope unobserved individuals may observe the younger generation's efforts on them. It would be great if the original design goal of "care for everyone" could be communicated to individuals who see the design.

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Appendix

Appendix – A: Participant information form - focus groups_dissertation

Title of the research project: Bariatric Patient Experience and the Dental Chair

Researcher: Lanbing Xu

1. Invitation Paragraph

You are being invited to participate in a research study. Before you decide whether to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and feel free to ask us if you would like more information or if there is anything that you do not understand. I would like to stress that you do not have to accept this invitation and should only agree to take part if you want to. Thank you for reading this.

2. What is the purpose of the study?

The aim of this research is to investigate and improve the experiences of bariatric patients through:

a. Brief exploration of bariatric oral care provision, pathways and accessibility issues

b. Detailed analysis and redesign of a bariatric dental chair.

3. Why have I been chosen to take part?

You have been chosen because you may have the experience of using dental chair.

4. Do I have to take part?

Participation in this focus group is voluntary.

5. What will happen if I take part?

If you decide to take part, you will be asked to take part in a focus group and to sign a consent

form. The focus group should take approximately 15 minutes to complete and will be conducted in English. It will take place in Teams meeting. During the focus group, you will be asked a series of questions related to your experiences. You will be asked to do so in a group of people who have been chosen in the same way as yourself. There are no incorrect answers and you are free to answer each question in as much detail as you like, or simply not at all. I would like to audio record the focus group. The audio files will be stored securely on a password-protect computer or University storage device until they can be transcribed into word documents, upon which they will be deleted. The transcripts will be anonymised and also stored securely.

6. Will I be offered any financial incentives to take part in the research?

I am not able to offer any payment or expenses for participating in the focus group.

7. Are there any risks in taking part?

There are no anticipated risks to you taking part in this focus group. I do not think that there are questions that should make you feel upset or uncomfortable. You are free to decline answer of any questions or to leave the focus group at any time, without giving a reason.

8. Are there any benefits in taking part?

There are no direct benefits to you taking part in the research, although you will be helping me to find out information that is important to my research aims.

9. What if I am unhappy or if there is a problem?

If you are unhappy, or if there is a problem, please feel free to let me know by contacting myself or my research supervisor (details below) and we will try to help. If you remain unhappy or have a complaint which you feel you cannot come to us with then you should contact the Research Ethics and Integrity Office at ethics@liv.ac.uk. When contacting the Research Ethics and Integrity Office, please provide details of the name or description of the study (so that it can be identified), the researcher(s) involved, and the details of the complaint you wish to make.

10. Will my participation be kept confidential?

I will store the focus group recordings securely on a password-protected computer or university storage device and provide access only to those individuals named on this information sheet. Each recording will be transcribed to a Word document whereupon all identifying information will be removed and the recording deleted. All transcribed data will be stored electronically and will be kept for up to 5 years, when it will be disposed of securely. This is in accordance with the University's data archiving procedures.

11. What will happen to the results of the study?

The results of this study will be used to write a research report and may lead to academic publication.

12. What will happen if I want to stop taking part?

If you begin the focus group and do not wish to continue, you stop at any time without giving a reason. If you wish to remove your data from the research after the focus group, you may do so within two weeks of the date of the focus group. After this time, the focus group will have been transcribed and all identifying information removed and therefore removal will no longer be possible.

13. Who can I contact if I have further questions?

Lanbing XU

L.xu22@student.liverpool.ac.uk

Appendix – B: Participant information form - interviews_dissertation

Title of the research project: [TO COMPLETE]

Researcher: [NAME OF STUDENT]

14. Invitation Paragraph

You are being invited to participate in a research study. Before you decide whether to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and feel free to ask us if you would like more information or if there is anything that you do not understand. I would like to stress that you do not have to accept this invitation and should only agree to take part if you want to. Thank you for reading this.

15. What is the purpose of the study?

The aim of this research is to investigate and improve the experiences of bariatric patients through:

a. Brief exploration of bariatric oral care provision, pathways and accessibility issues

b. Detailed analysis and redesign of a bariatric dental chair.

16. Why have I been chosen to take part?

You have been chosen because you are the expert in dental chair.

17. Do I have to take part?

Participation in this interview is voluntary.

18. What will happen if I take part?

If you decide to take part, you will be asked to take part in an interview and to sign a consent form. The interview should take approximately 30 minutes to complete and will be conducted in English. The interview will take place over the telephone/over Skype/in a suitable place of your choosing .

During the interview, you will be asked a series of questions related to your experiences. There are no incorrect answers and you are free to answer each question in as much detail as you like, or simply not at all. I would like to audio record your interview. The audio files will be stored securely on a password-protect computer or University storage device until they can be transcribed into word documents, upon which they will be deleted. The transcripts will be anonymised and also stored securely until the end of the academic year. The data will be used to write a research report.

19. Will I be offered any financial incentives to take part in the research?

I am not able to offer any payment or expenses for undertaking the interview.

20. Are there any risks in taking part?

There are no anticipated risks to you taking part in this interview. I do not think that there are questions that should make you feel upset or uncomfortable. You are free to decline answer of any questions or to stop the interview at any time, without giving a reason.

21. Are there any benefits in taking part?

There are no direct benefits to you taking part in the research, although you will be helping me to find out information that is important to my research aims.

22. What if I am unhappy or if there is a problem?

If you are unhappy, or if there is a problem, please feel free to let me know by contacting myself or my research supervisor (details below) and we will try to help. If you remain unhappy or have a complaint which you feel you cannot come to us with then you should contact the Research Ethics and Integrity Office at ethics@liv.ac.uk. When contacting the Research Ethics and Integrity Office, please provide details of the name or description of the study (so that it can be identified), the researcher(s) involved, and the details of the complaint you wish to make.

23. Will my participation be kept confidential?

I will store the interview recordings securely on a password-protected computer or university

storage device and provide access only to those individuals named on this information sheet. Each recording will be transcribed to a Word document whereupon all identifying information will be removed and the recording deleted. All transcribed data will be stored electronically and will be kept for up to 5 years, when it will be disposed of securely. This is in accordance with the University's data archiving procedures.

24. What will happen to the results of the study?

The results of this study will be used to write a research report and may lead to academic publication.

25. What will happen if I want to stop taking part?

If you begin the interview and do not wish to continue, you stop at any time without giving a reason. If you wish to remove your data from the research after the interview, you may do so within two weeks of the date of the interview. After this time, the interview will have been transcribed and all identifying information removed and therefore removal will no longer be possible.

26. Who can I contact if I have further questions?

Lanbing XU

L.xu22@student.liverpool.ac.uk

Appendix – C: Initial Design Brief

Bariatric Patient Experience and the Dental Chair

1. Background

1.1. *Bariatric patient experience and oral care services:*

Levels of obesity in the UK are increasing, and there is a need for oral care services to adapt to these patients' needs so that they are able to access quality care. Bariatric patients have numerous potential barriers to accessing dental care. These include the weight limits of the dental chair, inappropriate seating in the waiting area, inadequate toilet facilities, narrow corridors and the presence of stairs but no lift. Negative experiences and anxiety around accessing dental care can result in disengagement with services and ultimately lead to poor oral health. Understanding the practical and physiological considerations related to this patient group is important in managing their treatment and ensuring inclusive care.

1.2. *Bariatric dental chairs:*

When patients' weight exceeds that of a normal dental chair they are referred to specialist services with bariatric dental chairs. Bariatric dental chairs present numerous Usability issues which make them difficult for dentists to work with, and can affect the patients' care experience.

2. Brief

This project will seek to investigate and improve the experiences of bariatric patients through:

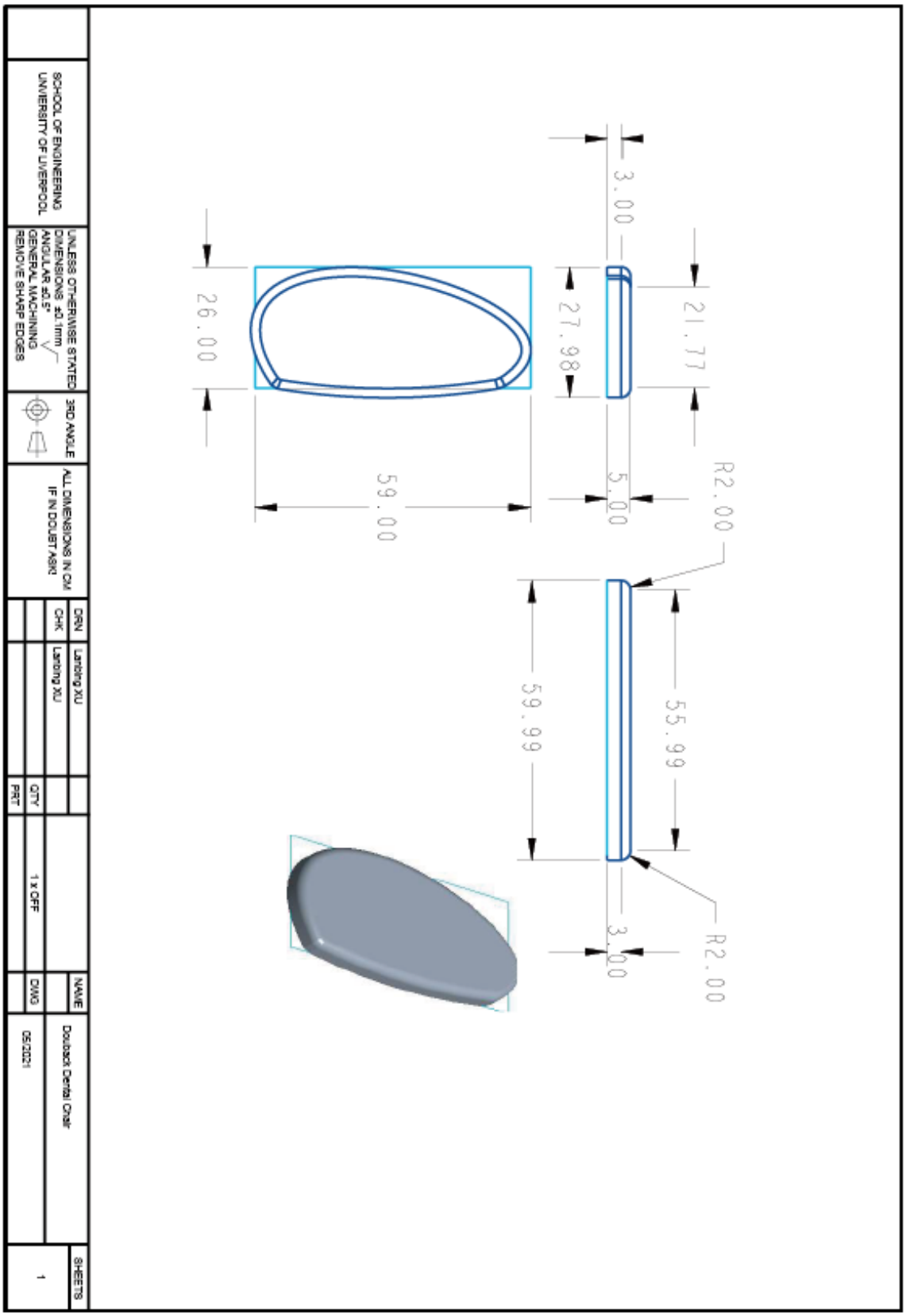
a. Brief exploration of bariatric oral care provision, pathways and accessibility issues
b. Detailed analysis and redesign of a bariatric dental chair.

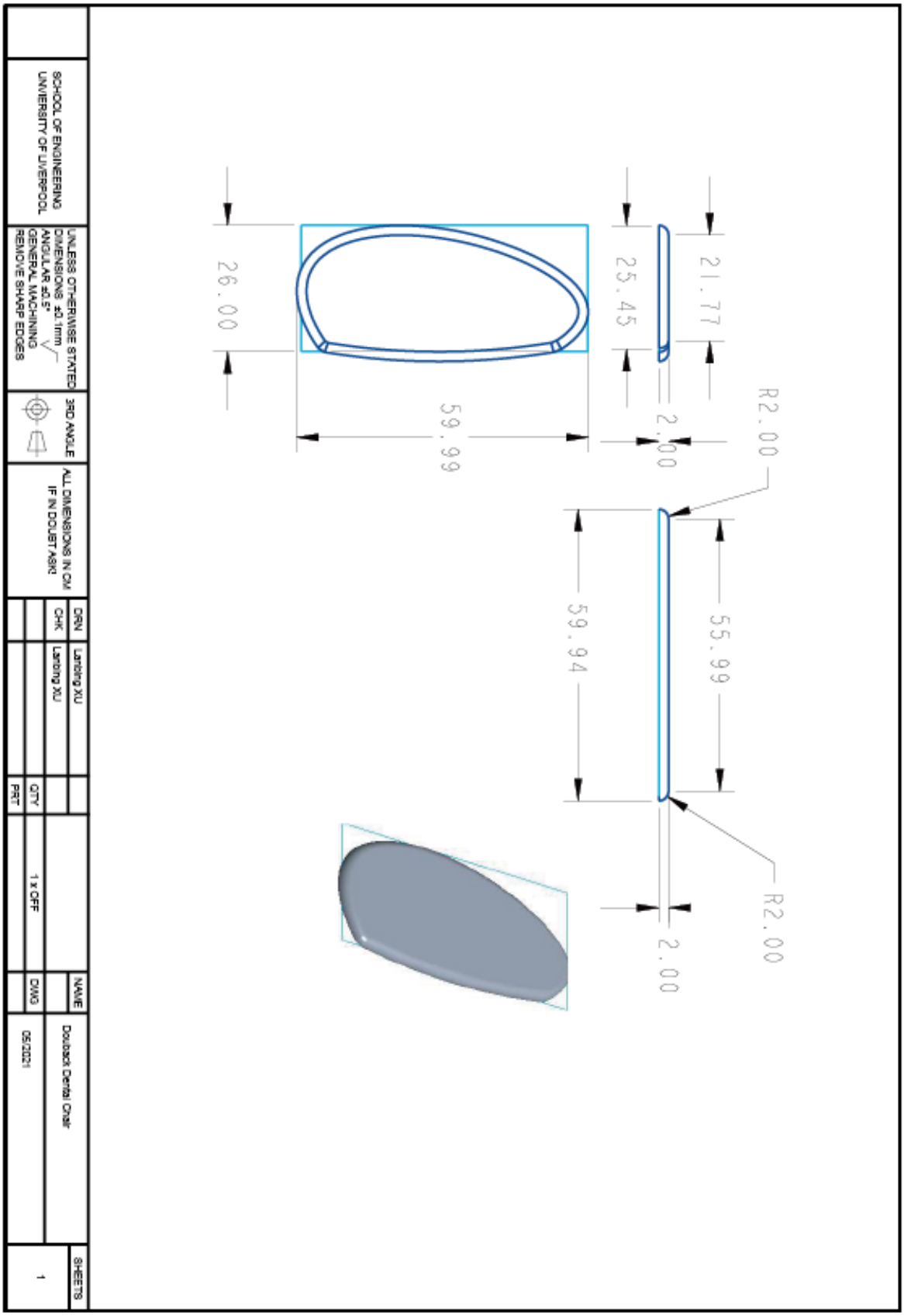
The outcome of this project will be a design improvement to a bariatric dental chair, with a focus on Usability. The solution could be the redesign of an integral feature, a modular add-on, or a separate product.

3. Project Activities

3.1. Explore bariatric patient experiences in accessing oral care services
3.2. Conduct a market analysis of existing bariatric dental chairs, and identify the key Usability issues
3.3. Choose one key issue to address through redesign
3.4. Test and evaluate the new design, and clearly demonstrate resulting improvements in Usability and bariatric patent experience

Appendix – D: Technical Drawings

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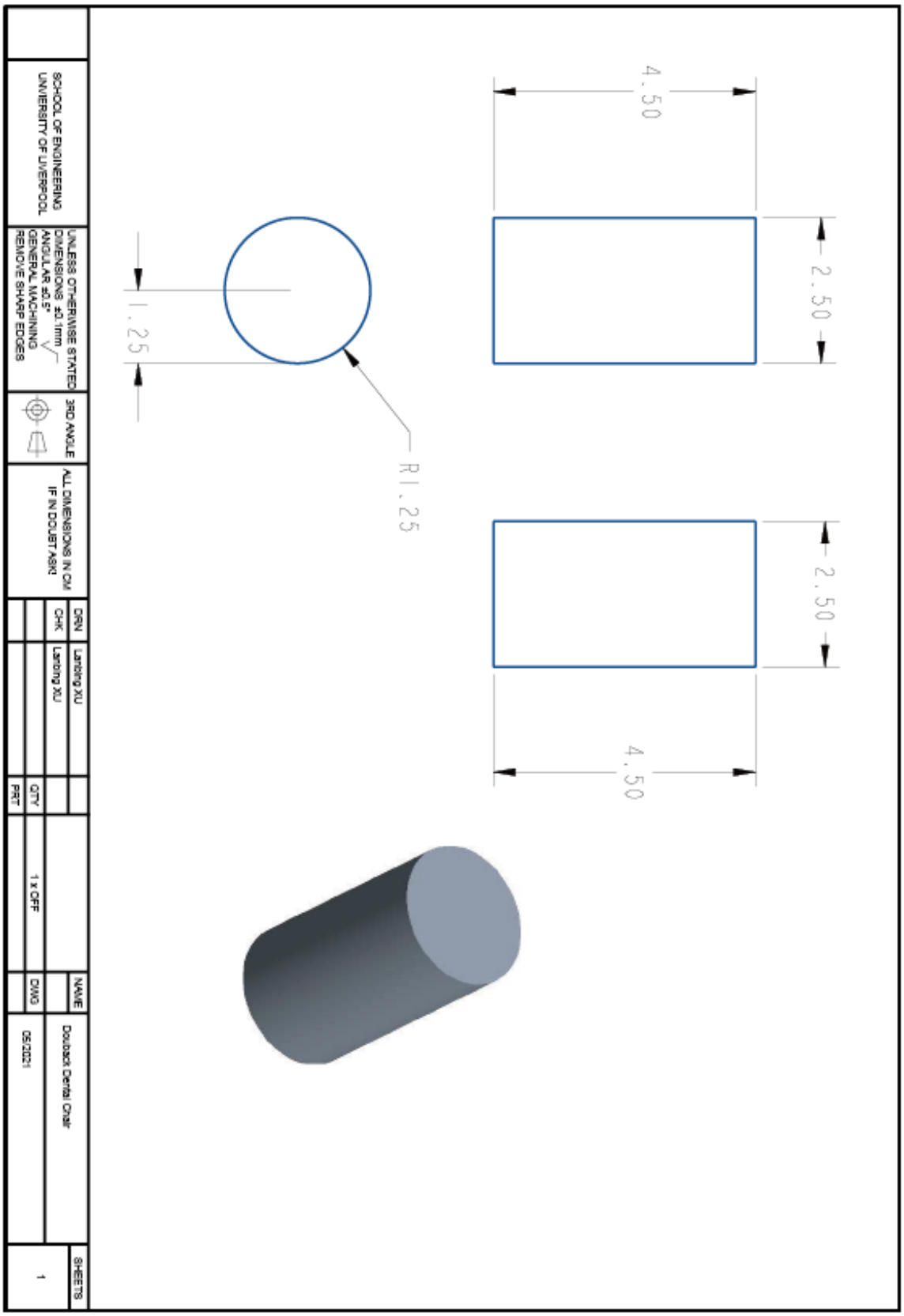
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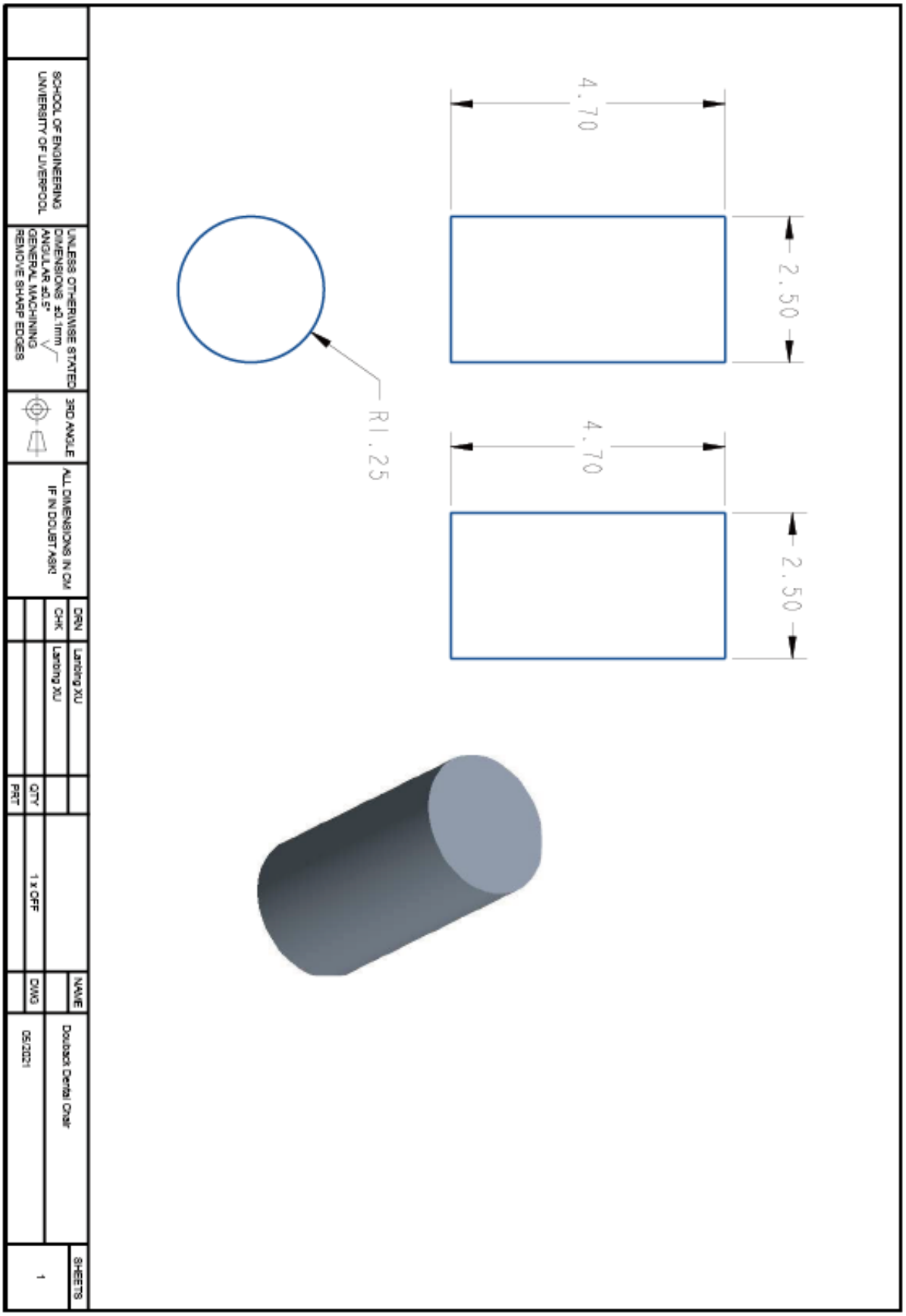
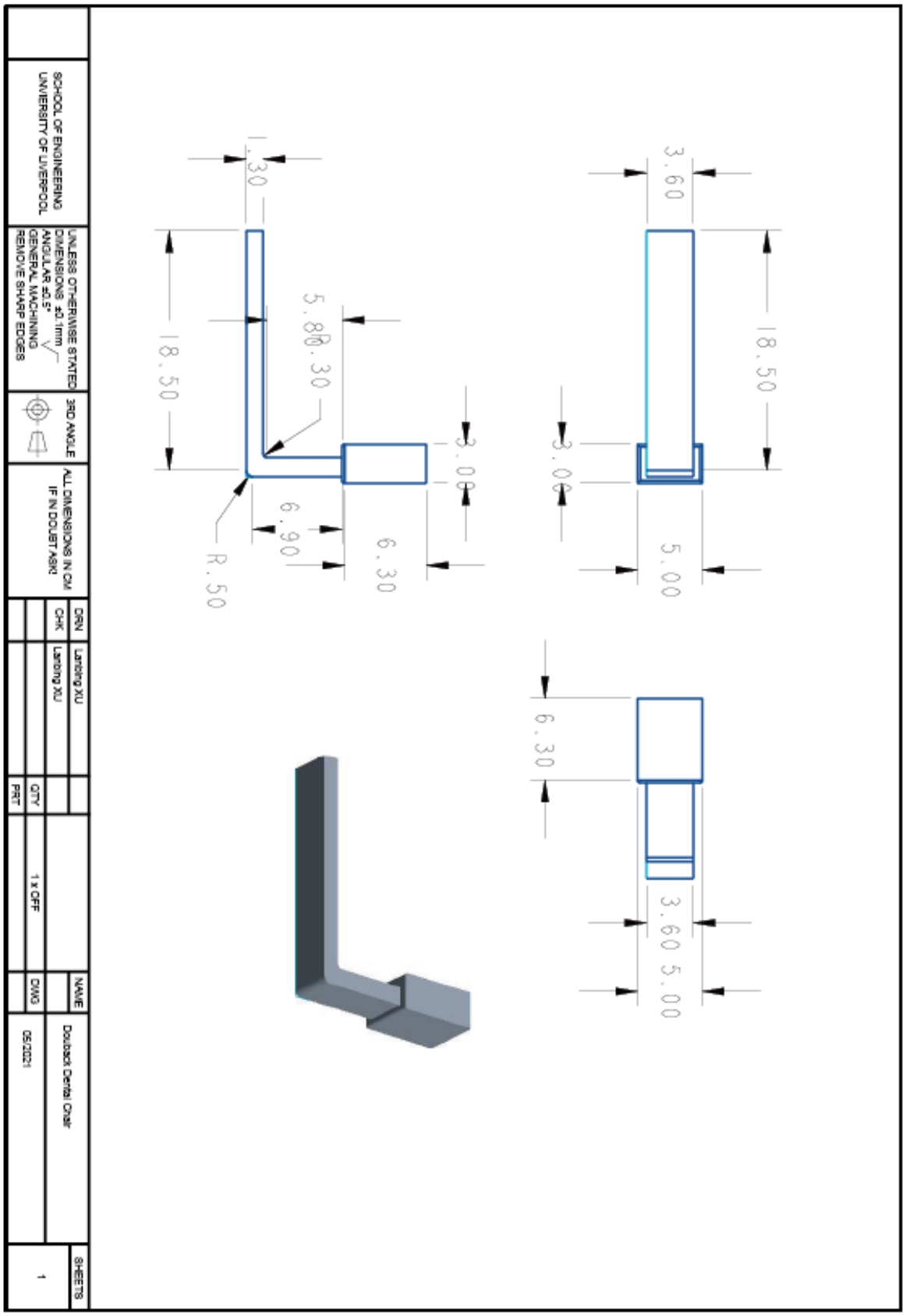
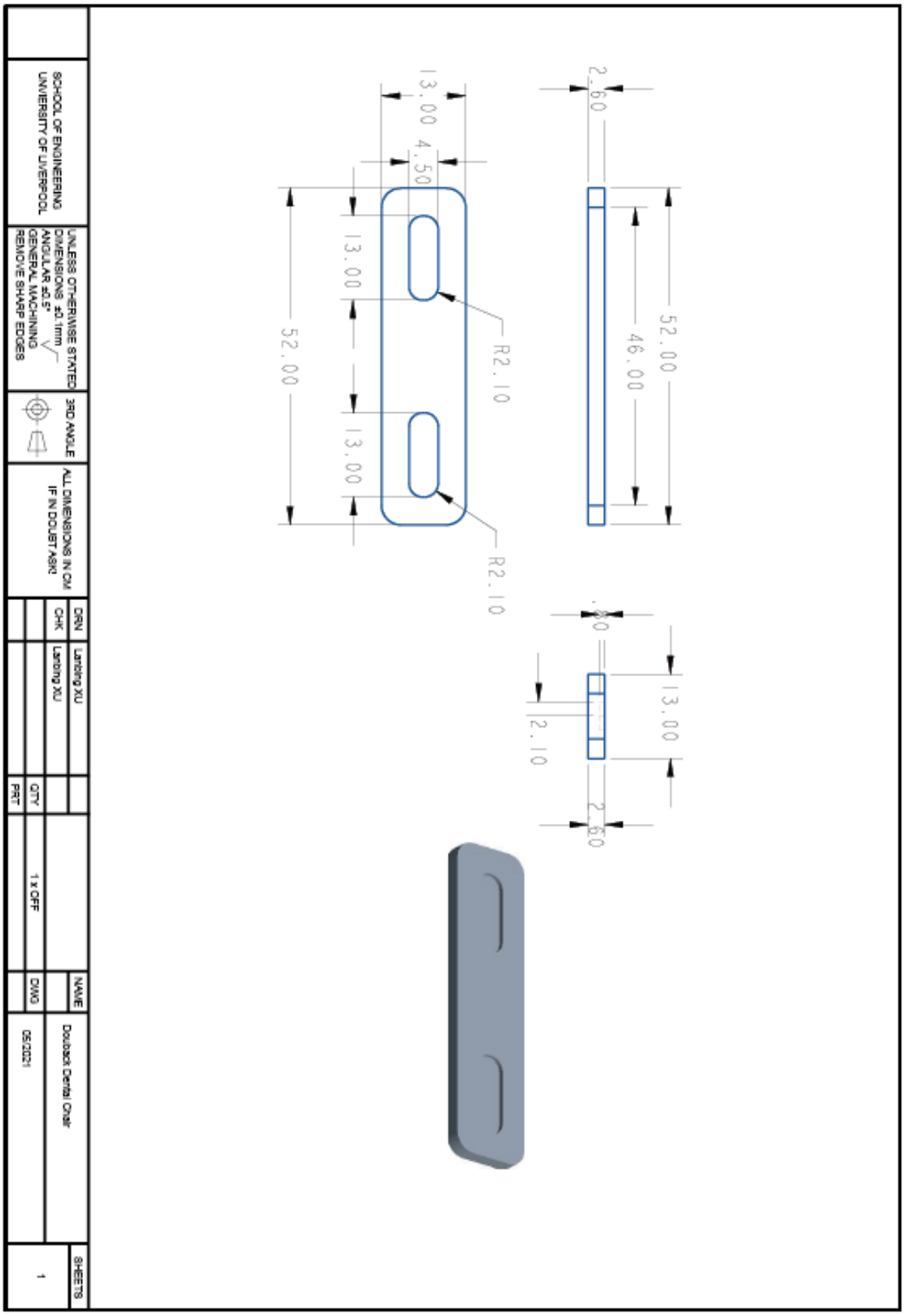
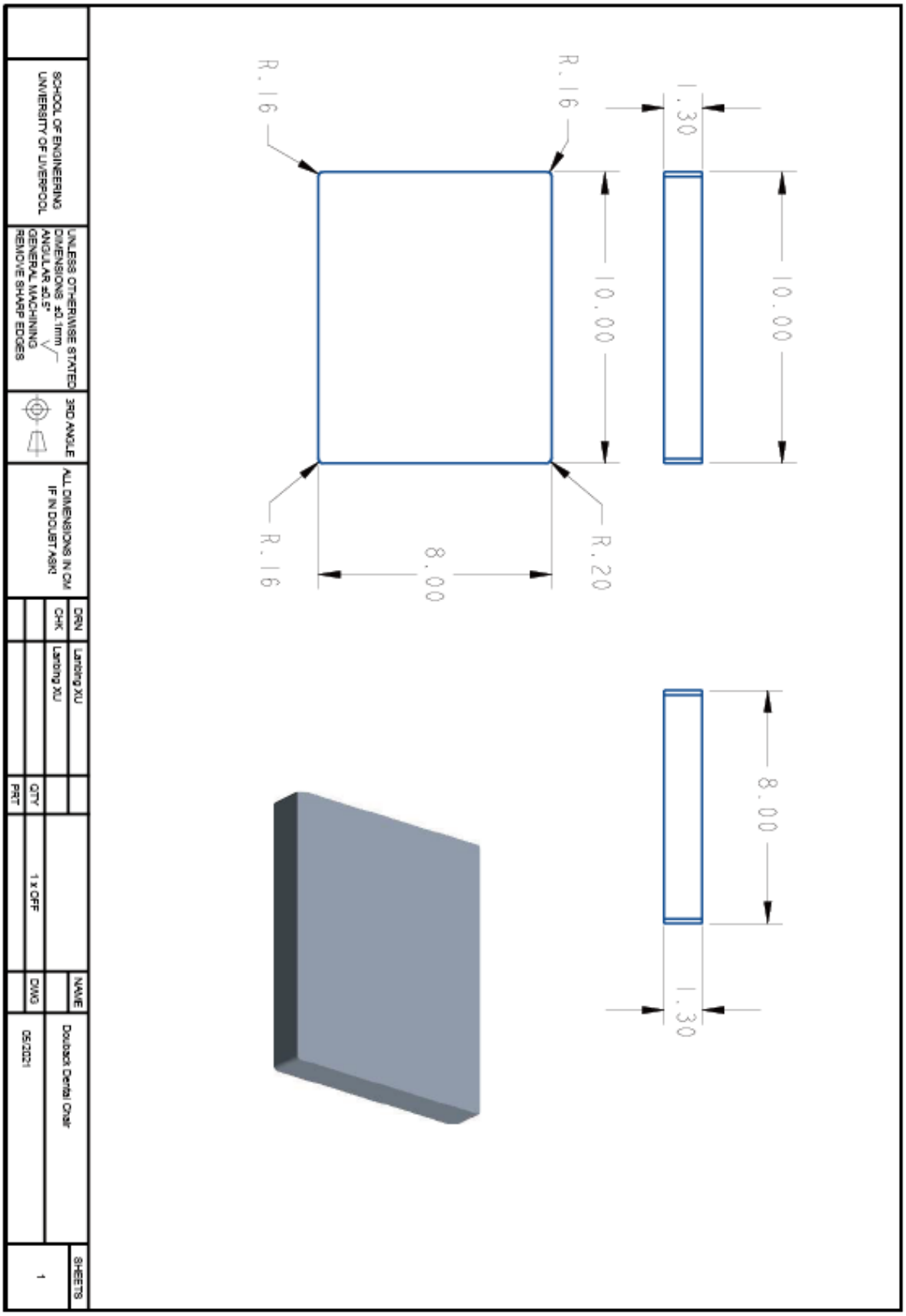
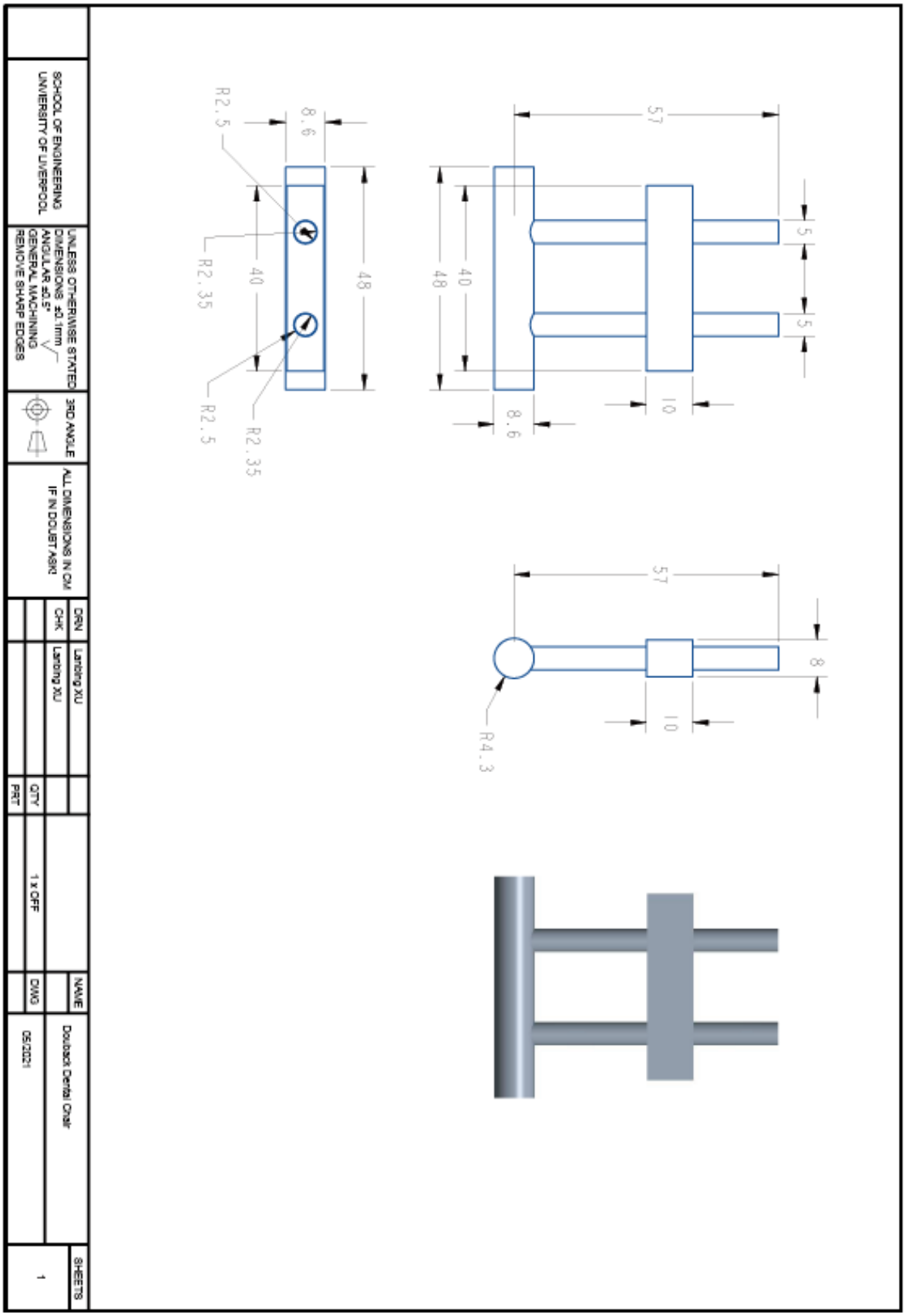
REMOVE SHARP EDGES
3RD ANGLE
ALL DIMENSIONS IN CM
IF IN DOUBT ASK!
DRN
Lanbing XU
CHK
Lanbing XU
QTY
1 x OFF
FRT
NAME
DWG
Doubock Dental Chair
05/2021
1
SHEETS


4.70
2.50
4.70
2.50
R1.25
SCHOOL OF ENGINEERING
UNIVERSITY OF LIVERPOOL
UNLESS OTHERWISE STATED
DIMENSIONS ±0.1mm
ANGULAR ±0.5°
GENERAL MACHINING
REMOVE SHARP EDGES
3RD ANGLE
ALL DIMENSIONS IN GM
IF IN DOUBT ASK!
DRN
CHK
Lanbing XU
Lanbing XU
QTY
PRT
1 x QTY
NAME
DWG
Doubock Dental Chair
05/2021
SHEETS
1


SCHOOL OF ENGINEERING
UNIVERSITY OF LIVERPOOL
UNLESS OTHERWISE STATED
DIMENSIONS ±0.1mm
ANGULAR ±0.5°
GENERAL MACHINING
REMOVE SHARP EDGES
3RD ANGLE
ALL DIMENSIONS IN CM
IF IN DOUBT ASK!
DRN
CHK
Lanbing XU
Lanbing XU
QTY
PRT
1 x CFF
NAME
DWG
Douback Dental Chair
05/2021
SHEETS
1
1.30
18.50
5.80
3.30
3.00
6.90
6.30
R.50
3.60
18.50
3.00
5.00
6.30
3.60
5.00


SCHOOL OF ENGINEERING
UNIVERSITY OF LIVERPOOL
UNLESS OTHERWISE STATED
DIMENSIONS ±0.1mm
ANGULAR ±0.5°
GENERAL MACHINING
REMOVE SHARP EDGES
3RD ANGLE
ALL DIMENSIONS IN CM
IF IN DOUBT ASK!
DRN
CHK
Lanbing XU
Lanbing XU
QTY
PRT
1 x OFF
DWG
NAME
Doubock Dental Chair
05/2021
1
SHEETS
2.60
13.00
4.50
13.00
13.00
52.00
R2.10
R2.10
52.00
46.00
2.60
13.00
2.10
2.60


SCHOOL OF ENGINEERING
UNIVERSITY OF LIVERPOOL
UNLESS OTHERWISE STATED
DIMENSIONS ±0.1mm
ANGULAR ±0.5°
GENERAL MACHINING
REMOVE SHARP EDGES
3RD ANGLE
ALL DIMENSIONS IN CM
IF IN DOUBT ASK!
DRN
CHK
Lanbing XU
Lanbing XU
QTY
PRT
1 x OFF
NAME
DWG
Douback Dental Chair
05/2021
1
SHEETS
R.16
R.16
R.16
R.20
10.00
10.00
8.00
1.30
8.00
1.30


SCHOOL OF ENGINEERING
UNIVERSITY OF LIVERPOOL
UNLESS OTHERWISE STATED
DIMENSIONS ±0.1mm
ANGULAR ±0.5°
GENERAL MACHINING
REMOVE SHARP EDGES
3RD ANGLE
ALL DIMENSIONS IN CM
IF IN DOUBT ASK!
DRN
CHK
Lanbing XU
Lanbing XU
QTY
1 x QTY
NAME
Doubock Dental Chair
DWG
05/2021
SHEETS
1
R2.5
8.6
R2.35
40
48
R2.5
R2.35
57
5
5
40
48
10
8.6
57
8
10
R4.3

Appendix – E: Rendering